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Faunistic and taxonomic investigations on the Odonata fauna of the Samoan archipelago with particular focus on taxonomic ambiguities in the "Ischnurine complex"

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Faunistic and taxonomic investigations on the Odonata fauna of the Samoan archipelago with particular focus on taxonomic ambiguities in the "Ischnurine complex"

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Abstract

New faunistic data is provided on the Odonata inhabiting the three main islands within the Samoan archipelago, namely Savai'i, Upolu and Tutuila as well as the smaller islands of Aunu'u and the Manu'a group. The specimens collected or observed in the field were compared to samples from other nearby Pacific island groups such as Fiji and Tonga.

This study makes important contributions towards resolving taxonomic issues regarding the *Ischnura* species described as endemic to Samoa and their relations to other Coenagrionidae genera. New diagnostic features for distinguishing between females of the endemic genera *Amorphostigma* and *Pacificagrion*, subspecies separation in the Pacific *Tramea transmarina* and distinguishing between Samoan *Hemicordulia*

species are suggested. *Anaciaeschna melanostoma* is proposed as junior synonym of *A. jaspidea*. A possible new subspecies of *Lathrecista asiatica*, confined to the Samoan archipelago, is discussed. The validity of *Agriocnemis interrupta* as a separate species from *A. exsudans* is questioned. Pacific *Pseudagrion* is believed to be represented within the region by one species only, with separate subspecies in Fiji, Tonga and Samoa, although more specimens from Fiji are required to resolve this issue.

Faatomu'aga

O ni fa'amatalaga fou ua mafai ona tu'ufa'atasia mai le aiga o iniseti e iai Se'emu/Mataga (Odonata) o loo ua fa'amauina nei mai atumotu e tolu o Samoa e aofia ai Savaii, Upolu ma Tutuila faatasi ai ma Aunu'u ma atumotu o Manu'a. O fa'amaumauga totino sa mafai ona aoina ma mai*tau*ina i taimi o suesuega sa fa'aaogaina e fa'atusatusa ma nisi o fa'amaumauga mai atumotu e pei o Fiti ma Toga.

O lenei suesuega e *tau*a tele lona sao i le tu'ufaatasia ma le fa'avasegaina o ituaiga iniseti e iai le *Ischnura* (nao Samoa e maua ai) aemaise lona feso'otaiga ma isi iniseti o le auaiga o le Coenagrionidae. O fa'amatalaga patino e mafai ai ona tu'uese'eseina iniseti fafine o le auaiga ua *tau*a o le *Amorphostigma* ma le *Pacificagrion* (na o le Pasefika e maua ai) ma le fa'avasegaina o le ituaiga o'iniseti e iai le Pacific *Tramea transmarina* ma le ituaiga e iai le Samoan *Hemicordulia* o loo mafai ona fa'amatalatalaina. O le ituaiga o le *Anaciaeschna jaspidea* ua suia nei lona igoa fou o le *A. melanostoma*. O se ituaiga iniseti fou ua masalomia e mai le ituaiga ua *tau*a o le *Lathrecist aasiactica* e patino lea i atumotu o Samoa o loo fa'amatalaina i lenei lipoti. O se manatu i le 'ese'esega o iniseti nei e lua e *tau*a o le *Agriocnemis interrupta* ma le *A. exsudans* o loo fesiligia pea. E iai le talitonuga o le ituaiga o le Pacific *Pseudagrion* oloo ta'atele i le itulagi o le Pasefika ma isi ituaiga o loo maua i Fiti, Toga ma Samoa ma e iai lava nai ese'esega laiti. Peitai e mo'omia le lava o iniseti o lea ituaiga e aoina mai Fiti e faia iai suesuega mo le faamautuina o lea manatu.

Key words: Samoa, faunistics, taxonomy, Ischnurine complex, *Amorphostigma* and *Pacificagrion*, subspecies separation, *Tramea transmarina*, *Hemicordulia*, *Anaciaeschna melanostoma, Anaciaeschna jaspidea, Lathrecista asiatica*, *Agriocnemis interrupta, Agriocnemis exsudans*.

Introduction

The Samoan islands possess nearly half of the Odonata species endemic for this Pacific region, yet many parts of the islands remain unexplored (Marinov et al. 2013a). Prior to Marinov et al. (2013a), Donnelly (1986), was the most recent worker to provide information on the Odonata species of these islands. Fraser (1925, 1926, 1927, and 1953) described a number of endemic species for Samoa, but Donnelly (1986) could not find most of them just 30 years after the completion of the last of

Fraser's reviews despite searching the same localities during the same time of year reported in Fraser's studies. The scarcity of the endemic Samoan Odonata prevented further work on their phylogenetic relationships. The cause of these species' apparent declines is unclear. Donnelly (1986) considered habitat degradation as improbable, but suggested that introduction of freshwater crayfish might be responsible.

We present here the results of a new study on the Odonata of the Samoan archipelago along with an update on their taxonomic and conservation status.

Material and Methods

The main islands of Savai'i, Upolu and Tutuila were visited by the first author between 2-23 July 2014. This is approximately the same time of year as Donnelly's (1986) survey. Smaller islands with freshwater resources were sampled as well, and specimens held in the entomological collection of the American Samoa Community College were also examined. Figure 1 shows the areas sampled during this study. Sampling localities are represented on Fig. 2.

Field work on Savai'i and Upolu islands was limited to general observations, due to logistical difficulties with obtaining a research permit and, getting to field sites as well as obtaining permission from the landowners to work on their properties. More

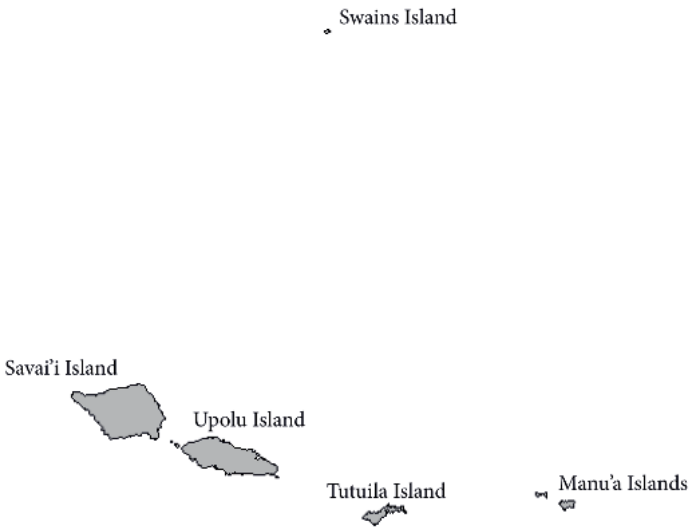
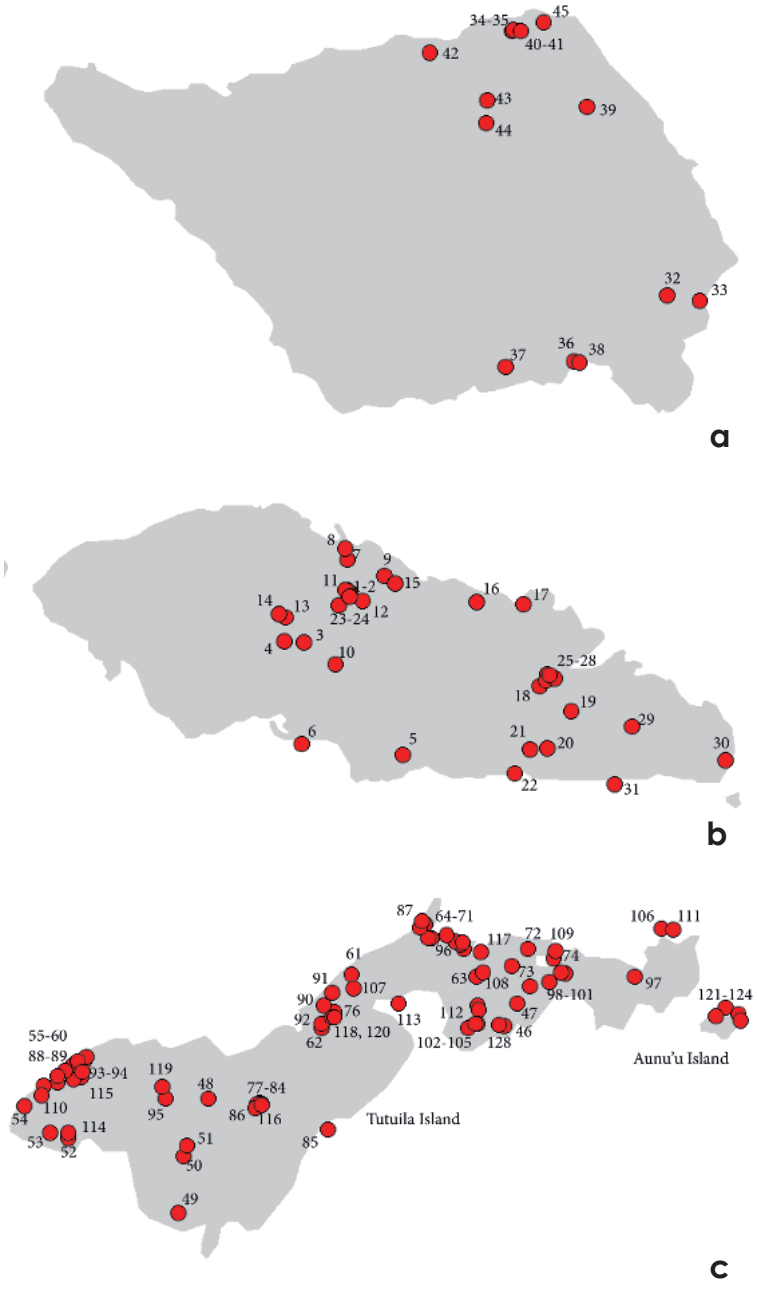


Figure 1. Sampling area in the Samoan archipelago and Swains Island.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Aunu'u Island
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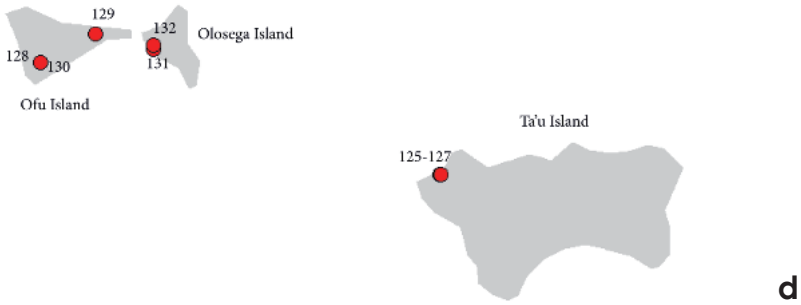

Figure 2. Sampling localities within individual islands: a) Savai'i, b) Upolu, c) Tutuila and Aunu'u, d) Manu'a Islands.

work could be done on Tutuila Island and other islands within American Samoa. Due to transportation challenges, field sampling in the Manu'a islands was restricted to two days only spent on the islands of Ofu and Olosega. Ta'u Island was not sampled.

The sampling scheme was determined based on the advice of local collaborators and the results from previous studies. Freshwater habitats were accessed from the main roads and sampled at the entrance to the habitat. Where the vegetation and the terrain allowed, the habitat was entered on foot. The search was abandoned if no flying individuals were encountered for a distance the width of the stream multiplied by ten, following the protocols of Harding et al. (2009). The focus was on adult Odonata. In a few occasions exuviae were collected with teneral individuals. These findings were very important as no larvae of the Samoan endemic Odonata have been described yet.

Adults were caught using an aerial net, killed in 70% ethanol, air-dried and transferred to paper envelopes. Diagnostic images were taken in the field for validating the true colour in live individuals. The dead insects were examined under a microscope to confirm the correct identification. Photos of diagnostic features were taken as described by Marinov et al. (2013a). Some of the photos were used to produce illustrations highlighting important characters for identification.

Identification of Samoan species was found to be problematic for the females when observed not in association with males. The original descriptions of the endemic genera *Amorphostigma* and *Pacificagrion* were based on males which have very distinctive fore wing pterostigmas. Females, however, cannot be differentiated based on this characters states as they do not have the typical shape given in the original descriptions for males. Previously the descriptions of the females were made on supposition based on general similarity to the males. Therefore, a new set of morpho-

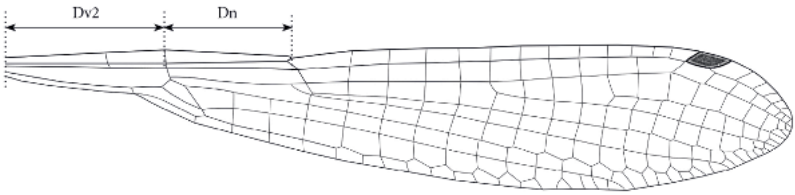

Figure 3. Calculating the prenodal index: Prn = Dv2/Dn, where Dv2 – distance from the base of the wing to the second predonal vein, and Dn – distance from the second prenodal vein to the nodus.

logical characters was sought for differentiating females of the Samoan endemic Zygoptera. Characters such as the shape of head, legs, pterostigmas and ovipositor were explored. In addition we introduce a new character, the pre-nodal index: Prn = Dv2/Dn, where Dv2 is the distance from the base of the wing to the second prenodal cross vein and Dn is the distance from the second prenodal vein to the nodus (Fig. 3). Prn was found helpful in distinguishing between the taxa at the generic level when used in conjunction with other characters suggested below as diagnostic.

The list of the sampling localities below includes all sites visited during the present study and unpublished data from previous work. Not all localities produced Odonata sightings, but they are included here anyway to show the coverage for the present study. Localities with no specified collector name were sampled by the principal investigator. Additional data obtained for this study come from other field studies and specimens in the American Samoa Community College collection taken by the following collectors: Dan Polhemus (DP), Mark Schmaedick (MS), Neil Gurr (NG), McConnell Dowell Construction (MCDC), Niela Leifi (NL), Kenneth Marcos (KM) and Joshua O. Seamon (JOS).

Sampling localities

Upolu Island

1. Stream and Botanical Garden by the Robert Louis Stevenson Museum, Vailima (-13.8685, -171.7661; 548 m a.s.l.): 02, 21 July 2014.
2. Tourist track on the way to Robert Louis Stevenson's tomb (-13.865975, -171.7686; 278 m a.s.l.): 02, 21 July 2014.
3. Tourist track to Lake Lanoto'o (-13.9136, -171.8084; 744 m a.s.l.): 03 July 2014.
4. Lake Lanoto'o (-13.9126, -171.8261; 792 m a.s.l.): 03 July 2014.
5. Togitogiga River and waterfall by the road Siumu-Salani (-14.0156, -171.71809; 50 m a.s.l.): 03 July 2014.
6. Tafitoala River and waterfall by the village of Tafitoala (-14.0052, -171.8097; 22 m a.s.l.): 03 July 2014.
7. Vailima Stream, Apia by the bridge on Atenae St (-13.8389, -171.7689; 7 m a.s.l.): 07 July 2014.

8. Fish market, Apia (-13.8292, -171.7707; 6 m a.s.l.): 07 July 2014.
9. River SE of the Fagalii Domestic airport (-13.8537, -171.7352; 40 m a.s.l.): 08, 22 July 2014.
10. Tiavi River above the village of Malololelei (-13.9334, -171.7795; 747 m a.s.l.): 21 July 2014.
11. By the Robert Louis Stevenson's tomb (-13.8664, -171.7709; 437 m a.s.l.): 21 July 2014.
12. At the confluence of Vaiole moli River, Faasologaafu River and Vai o le fee River by the village of Alaloa (-13.8758, -171.7548; 122 m a.s.l.): 21 July 2014.
13. Papaseea River by the village of Papaseea (-13.8909, -171.8248; 392 m a.s.l.): 22 July 2014.
14. Tapatapao River N from the village of Papaseea (-13.8878, -171.8305; 366 m a.s.l.): 22 July 2014.
15. Malua River by the village of Letogo (-13.8606, -171.7249; 30 m a.s.l.): 22 July 2014.
16. River by the village of Solosolo (-13.8767, -171.6510; 22 m a.s.l.): 22 July 2014.
17. Wetland by the village of Saoluafata (-13.8787, -171.6082; 22 m a.s.l.): 22 July 2014.
18. Waterfall by the village of Lemafa (-13.9532, -171.5931; 208 m a.s.l.): 22 July 2014.
19. Roadside on the Richardson Rd by the EPC dam (-13.9765, -171.5648; 398 m a.s.l.): 22 July 2014.
20. Mulivaifagatola River (-14.0092, -171.5871; 254 m a.s.l.): 22 July 2014.
21. River by the village of Salani (-14.0106, -171.6028; 163 m a.s.l.): 22 July 2014.
22. Small creek E of the village of Salani (-14.0319, -171.6167; 87 m a.s.l.): 22 July 2014.
23. Vaoala River (-13.8799, -171.7764; 326 m a.s.l.): 22 July 2014.
24. Stream crossing Tuluiga Rd (-13.8725, -171.7669; 294 m a.s.l.): 22 July 2014.
25. Small waterfall by the village of Lemafa (-13.9422, -171.5862; 123 m a.s.l.): 23 July 2014.
26. Small waterfall the village of Lemafa (-13.9480, -171.5874; 133 m a.s.l.): 23 July 2014.
27. A series of roadside seepages above the village of Taelefaga (-13.9463, -171.5793; 132 m a.s.l.): 23 July 2014.
28. Top of the ridge above the village of Taelefaga (-13.9432, -171.5845; 240 m a.s.l.): 23 July 2014.
29. River crossing Richardson Rd about 5 km E of the EPC dam (-13.9898, -171.5094; 331 m a.s.l.): 23 July 2014.
30. Wetland between the villages of Malaela and Lotopue (-14.0202, -171.4244; 24 m a.s.l.): 23 July 2014.
31. River by the village of Lepa (-14.0423, -171.5253; 7 m a.s.l.): 23 July 2014.

Savai'i Island

32. Remnant pools on the bed of a stream above the village of Lalomalava (-13.6934, -172.23083; 88 m a.s.l.): 04 July 2014.
33. River crossing the Main North Coast Rd N of the village of Lalomalava (-13.6986, -172.2014; 24 m a.s.l.): 04 July 2014.
34. River above the village of Manase (-13.4526, -172.3726; 60 m a.s.l.): 04 July 2014.
35. River mouth E of the village of Manase (-13.4515, -172.3710; 12 m a.s.l.): 04 July 2014.
36. Faleata River and tributary by the Afu Aau waterfalls (-13.7533, -172.3164; 3 m a.s.l.): 05 July 2014.
37. River and tributary by the village of Sili (-13.7581, -172.3784; 45 m a.s.l.): 05 July 2014.

38. Atua*tau*tunu Wetland by the village of Vailoa (-13.7546, -172.3110; 22 m a.s.l.): 05 July 2014.
39. Maliolio River by the village of Patamea (-13.5218, -172.3044; 59 m a.s.l.): 05 July 2014.
40. River between the villages of Saleia and Avao (-13.4520, -172.3644; 0 m a.s.l.): 05 July 2014.
41. Wetland by the village of Vaisala (-13.4520, -172.3645; 20 m a.s.l.): 06 July 2014.
42. Wetland by the village of Sasini (-13.4716, -172.4474; 13 m a.s.l.): 06 July 2014.
43. Tourist track to the Mt Matavanu crater by the warden's house (-13.5159, -172.3955; 350 m a.s.l.): 06 July 2014.
44. Top of the Mt Matavanu crater (-13.5363, -172.3958; 660 m a.s.l.): 06 July 2014.
45. Wetland by the village of Satoalepai (-13.4442, -172.3441; 3 m a.s.l.): 07 July 2014.

Tutuila Island

46. Small waterfall roadside S of Tisa's Place, village of Alega (-14.2885, -170.6422; 13 m a.s.l.): 08 July 2014.
47. Stream by the village of Alega (-14.2795, -170.6372; 3 m a.s.l.): 08 July 2014.
48. Lago Spring, 800 m E of Aoloaufou (-14.3176, -170.7615; 374 m a.s.l.): 16 March 2009 (DP); 11, 12, 17 July 2014.
49. Open grass area alongside the beach by the village of Taputimu (-14.3637, -170.7736; 29 m a.s.l.): 11 July 2014.
50. Overgrown channel in the village of Malaeloa (-14.3410, -170.7711; 51 m a.s.l.): 11 July 2014.
51. Taro field within a former wetland by the village of Malaeloa (-14.3366, -170.7701; 40 m a.s.l.): 11 July 2014.
52. Seepage roadside E of the village of Agugulu (-14.3339, -170.8178; 16 m a.s.l.): 12 July 2014.
53. Seepage roadside SE of the village of Amanave (-14.3314, -170.8250; 11 m a.s.l.): 12 July 2014.
54. Grass vegetation by the sea shore by the village of Poloa (-14.3206, -170.8354; 24 m a.s.l.): 12 July 2014.
55. Seepage SW of the village of Fagamalo (-14.3027, -170.8111; 85 m a.s.l.): 12 July 2014.
56. Stream by the village of Fagamalo (-14.3008, -170.8103; 13 m a.s.l.): 12 July 2014.
57. Stream by the village of Maloata (-14.3090, -170.8126; 29 m a.s.l.): 12 July 2014.
58. Stream N of the village of Fagalii (-14.3102, -170.8154; 16 m a.s.l.): 12 July 2014.
59. Stream by the village of Fagalii-1 (-14.3113, -170.8219; 37 m a.s.l.): 12 July 2014.
60. Stream by the village of Fagalii-2 (-14.3128, -170.8274; 31 m a.s.l.): 12 July 2014.
61. Mt. Alava Trail on the top hill of the National Park of American Samoa (-14.2681, -170.7039; 331 m a.s.l.): 13 July 2014.
62. Leele Stream above the village of Fagasa (-14.2895, -170.7160; 94 m a.s.l.): 13 July 2014.
63. A cascade of roadside pools above the village of Aua (-14.2688, -170.6533; 76 m a.s.l.): 13 July 2014.
64. National Park of American Samoa, stream by the village of Amalau (-14.2575, -170.6586; 52 m a.s.l.): 13, 14 July 2014.

65. Seepage about W from the village of Amalau-1 (-14.2557, -170.6599; 27 m a.s.l.): 13 July 2014.
66. Seepage about W from the village of Amalau-2 (-14.2545, -170.6620; 2 m a.s.l.): 13 July 2014.
67. Seepage about W from the village of Amalau-3 (-14.2522, -170.6655; 71 m a.s.l.): 13 July 2014.
68. Wetland at the E end of the village of Vatia-1 (-14.2534, -170.6715; 13 m a.s.l.): 13, 14 July 2014.
69. Wetland at the beginning of the Tuafuna Trail, Vatia Village (-14.2479, -170.6739; 0 m a.s.l.): 14, 18 July 2014.
70. Wetland at the E end of the village of Vatia-2 (-14.2534, -170.6727; 0 m a.s.l.): 18 July 2014.
71. Wetland behind the church in the village of Vatia (-14.2490, -170.6761; 10 m a.s.l.): 18 July 2014.
72. Wetland at the village of Masefau (-14.2574, -170.6329; 0 m a.s.l.): 18 July 2014.
73. Small creek above the village of Masefau (-14.2643, -170.6394; 10 m a.s.l.): 18 July 2014.
74. Seepage above the village of Masefau (-14.2613, -170.6224; 20 m a.s.l.): 18 July 2014.
75. Concrete pool created at the course of a stream flowing through the town of Pago Pago (coordinates not obtained): 18 July 2014.
76. Pago Pago; in concrete-lined reservoir (-14.2830, -170.7105; 92 m a.s.l.): 12 December 2003 (NG).
77. Malaeimi Village; in flight over cut grass and gravel (-14.3199, -170.7413; 48 m a.s.l.): 02 April 2010 (MS).
78. Malaeimi Village; in nursery screenhouse (-14.3196, -170.7409; 47 m a.s.l.): 01 May 2009 (MS).
79. Malaeimi Village; at light at night (-14.3200, -170.7412; 47 m a.s.l.): 16 February 2006 (MS).
80. Malaeimi Village; resting on exterior building wall (-14.3201, -170.7414; 49 m a.s.l.): 26 June 2009 (MS).
81. Malaeimi Village; flying near pond (-14.3202, -170.7399; 42 m a.s.l.): 12 May 2004 (NG).
82. Malaeimi Village; near pond edge (-14.3201, -170.7401; 43 m a.s.l.): 12 May 2004 (KM).
83. Malaeimi Village; flying near forest edge (-14.3202, -170.7419; 51 m a.s.l.): 17 February 2006 (MS).
84. Malaeimi Village; trapped inside building (-14.3201, -170.7415; 49 m a.s.l.): 27 January 2010 (MS).
85. Tafuna airport (-14.3303, -170.7131; 0 m a.s.l.): 01 July 2004 (MCDC).
86. Mapusaga Village: at light at night (-14.3217, -170.7423; 47 m a.s.l.): 14 July 2012 (MS).
87. Vatia Village; malaise trap in secondary scrub forest (-14.2463, -170.6756; 2 m a.s.l.): 24-25 June, 30 June – 01 July and 4-5 July 2012 (NL).
88. Maloata Village; swamp (-14.3045, -170.8158; 0 m a.s.l.): 13 February 2004 (NG).
89. Dripping rock face in gully above road, NE of Fagalii (-14.3067, -170.8189; 117 m a.s.l.): 18 August 2012 (DP).

90. Spring fed pools along ridge trail near Futifuti Mountain, 400 m N of Fagasa Pass summit (-14.28039, -170.7150; 198 m a.s.l.): 18 March 2009 (DP).
91. Pools in trail along summit ridge, NE of Fatifati Mountain, 1 km (straight line) NE of Fagasa Pass (-14.2750, -170.7117; 300 m a.s.l.): 22 March 2009 (DP).
92. Le'ele Stream, near Fagasa (-14.2875, -170.7158; 82 m a.s.l.): 19 March 2009 (DP).
93. Roadside seeps NW of Maloata Stream crossing (-14.3028, -170.8139; 66 m a.s.l.): 20 March 2009 (DP).
94. Maloata Stream above road crossing, SE of Maloata (-14.3069, -170.8122; 29 m a.s.l.): 20 March 2009 (DP).
95. Spring at head of headwater tributary to Vaisa Stream, W side of Faleselau Ridge, NW of Aoloaufou (-14.3178, -170.7786; 334 m a.s.l.): 21 March 2009 (DP).
96. Rocky stream in Amalau Valley, 650 m NW of Afono on road to Vatia (-14.2550, -170.6592; 31 m a.s.l.): 21 August 2007 (DP).
97. Lepa Stream, 1.2 km SW of Aoa (-14.2686, -170.5897; 60 m a.s.l.): 16 March 2009 (DP).
98. Muliolevai Stream, above Auto, shaded midreach in forest above village (-14.2728, -170.6319; 25 m a.s.l.): 25 September 2014 (DP).
99. Small un-named stream above Amaua, shaded midreach in forest above village (-14.2708, -170.6244; 25 m a.s.l.): 25 September 2014 (DP).
100. Auvai Stream, above Fagaitua, unshaded midreach at upper bridge in village (-14.2675, -170.6178; 18 *m.* a.s.l.): 24 September 2014 (DP).
101. Auvai Stream, above Fagaitua, shaded midreach in forest above village (-14.2669, -170.6197; 50 m a.s.l.): 24 September 2014 (DP).
102. Vaitele Stream, above Laulii, head of shaded midreach at falls above village (-14.2894, -170.6567; 20 m a.s.l.): 26 September 2014 (DP).
103. Vaitele Stream, above Laulii, shaded midreach above Laulii village (-14.2803, -170.6531; 15 m a.s.l.): 26 September 2014 (DP).
104. Vaitele Stream, above Laulii, unshaded midreach in Laulii village (-14.2819, -170.6525; 5 m a.s.l.): 26 September 2014 (DP).
105. Vaitele Stream, above Laulii (-14.2878, -170.6531; 0 *m.* a.s.l.): 26 September 2014 (DP).
106. Roadside seep over bedrock, 500 m E of Onenoa (-14.2492, -170.5789; 25 m a.s.l.): 26 September 2014 (DP).
107. Vaipito Stream, Pago Pago, terminal reach at road bridge near back end of harbor (-14.2733, -170.7031; 0 m a.s.l.): 28 September 2014 (DP).
108. Pago Stream headwater seeps and ditches along N side of Afono Pass road (-14.2672, -170.6508; 75 m a.s.l.): 28 September 2014 (DP).
109. Small waterfall 800 m E of Masefau (-14.2586, -170.6217; 46 m a.s.l.): 16 March 2009 (DP).
110. Vaitele Stream upstream of road bridge, above Poloa (-14.3167, -170.8286; 72 m a.s.l.): 20 March 2009 (DP).
111. Abandoned tilapia farm and capped spring on Lefau Ridge, N of Tula (-14.2497, -170.5744; 55 *m.* a.s.l.): 26 September 2014 (DP).
112. Vaiola Stream at road crossing in National Park (-14.2878, -170.6539; 53 *m.* a.s.l.): 28 September 2014 (DP).

113. Spring fed pools in roadside ditch at Utulei, behind Pago Pago convention center (-14.2797, -170.6850; 6 m a.s.l.): 17 March 2009 (DP).
114. Roadside seeps at Fagaone Point, SW of Seetaga (-14.3317, -170.8178; 9 m a.s.l.): 20 March 2009 (DP).
115. Stream above Fagalii at road crossing (-14.3089, -170.8222; 50 m a.s.l.): 18 August 2012.
116. Pond at American Samoa Community College (-14.3203, -170.7400; 46 m a.s.l.): 16 March 2009 (DP).
117. Pago Stream terminal reach at Afono village bridge (-14.2589, -170.6517; 0 *m*. a.s.l.): 28 September 2014 (DP).
118. Headwater streamlet of Vaipito Stream crossing Fagasa Pass road in upper Vaipito Valley, behind Pago Pago (-14.2850, -170.7114; 131 m a.s.l.): 18 March 2009 (DP).
119. Bog in forest at headwaters of Vaisa Stream, NW of Aoloaufou (-14.31306, -170.7797; 320 m a.s.l.): 21 March 2009 (DP).
120. Headwaters of Vaima Stream (trib. to Vaipito Stream) crossing Fagasa Pass road in upper Vaipito Valley, behind Pago Pago (-14.2853, -170.7106; 113 m a.s.l.): 18 March 2009 (DP).

Aunu'u Island

121. Pala Lake at the N part of the island (-14.2812, -170.5531; 0 m a.s.l.): 09 July 2014.
122. Faimulivai Marsh (-14.2839, -170.5481; 10 m a.s.l.): 09, 19 July 2014.
123. Outlet of Faimulivai Marsh (-14.2865, -170.5472; 15 m a.s.l.): 09 July 2014.
124. Taro fields and canals (-14.2848, -170.5573; 14 m a.s.l.): 09, 19 July 2014.

Ta'u Island

125. Trapped in screenhouse plant nursery (-14.2282, -169.5113; 60 m a.s.l.): 03 February 2010 (MS).
126. At light at night (-14.2280, -169.5114; 60 m a.s.l.): 01 February 2010 (MS).
127. On mixed weedy vegetation (-14.2280, -169.5110; 62 m a.s.l.): 04 February 2010 (MS).

Ofu Island

128. Vaoto marsh (-14.2881, -170.6446; 5 m a.s.l.): 15 July 2014.
129. Well in the To'aga area (-14.1728, -169.6464; 10 m a.s.l.): 16 July 2014.
130. On low weedy vegetation near airport (-14.1841, -169.6680; 4 m a.s.l.): 16 June 2011 (MS).

Olosega Island

131. Well within the village of Olosega (-14.1791, -169.6235; 5 m a.s.l.): 16 July 2014.
132. Olosega marsh (-14.1775, -169.6236; 3 m a.s.l.): 16 July 2014.

Swains Island

133. Locality not specified (-11.0558, -171.0774; 0 m a.s.l.): 18 February 2002 (JOS).
134. On vegetation at lagoon edge (-11.0551, -171.0847; 0 m a.s.l.): 23 September 2012 (MS).

Results

Species identification

Females of the Samoan endemic Zygoptera genera are difficult to differentiate based on the original descriptions. Therefore, more features were sought that could potentially be used as diagnostic at the generic level. Diagnostic characters are provided below for the females of *Amorphostigma* and *Pacificagrion* only. These are provisional and have been developed for this study only. The validity of some of them, like occipital area and hind leg femora with associated spines must be validated before accepted as truly diagnostic.

Table 1. Pre-nodal index values for Samoan Zygoptera.

Species	Min	Max	Average	N
Ischnura heterosticta	1,00	1,15	1,06	7
Agriocnemis exsudans	1,00	1,25	1,13	40
Ischnura aurora	1,05	1,26	1,14	11
Pseudagrion samoesne	1,12	1,24	1,16	5
Pacificagrion lachrymosa	1,13	1,21	1,17	2
Pseudagrion m. microcephalum	1,17	1,22	1,20	4
Pacificagrion sp.	1,17	1,25	1,21	2
Pseudagrion m. stainbergerorum	1,19	1,25	1,23	3
Pseudagrion pacificum	1,25	1,25	1,25	1
Amorphostigma sp. nov.	1,28	1,50	1,39	18
Amorphostigma armstrongi	1,33	1,55	1,43	25

Table 1 introduces the Prn calculated for the Zygoptera genera sampled during this study. *Ischnura heterosticta* (Burmeister, 1842), a wide spread Pacific species, is included for comparison with a congeneric species occuring in Samoa. All Prn score ranges are plotted on Figure 4. Using this character *Amorphostigma* can be easily differentiated as having the highest score (between 1.39-1.43). The distinction bet-

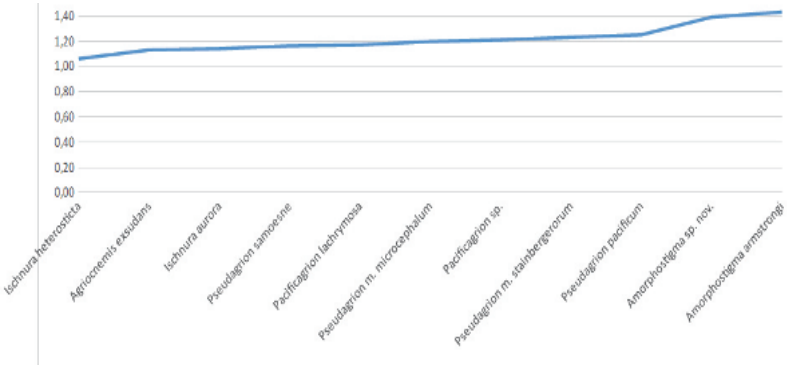

Figure 4. Prenodal index range for selected Samoan Zygoptera genera and species.

ween some of the other genera was more difficult based on this character only as some of them share similar scores: *Ischnura* + *Agriocnemis* between 1.06-1.14 and *Pseudagrion* + *Pacificagrion* between 1.16-1.25.

Endemic *Ischnura* from Samoa were not collected during this study and types have been investigated by photos only which is not enough to provide any sufficient characteristic.

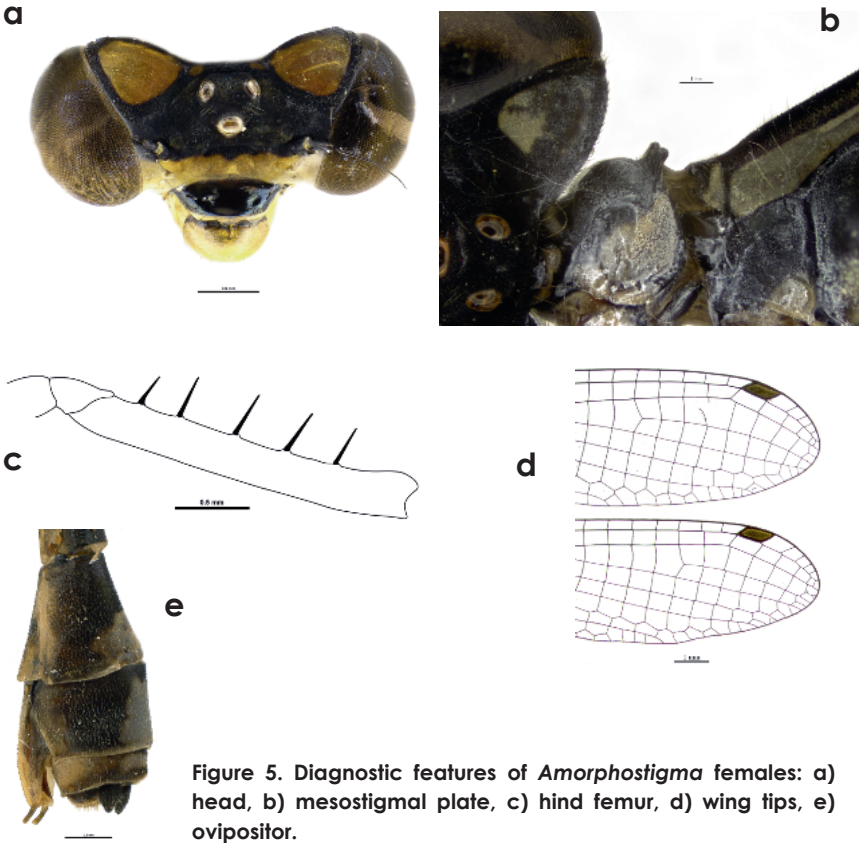

Figure 5. Diagnostic features of *Amorphostigma* females: a) head, b) mesostigmal plate, c) hind femur, d) wing tips, e) ovipositor.

Diagnostis of *Amorphostigma* females (Fig. 5)

The distance between the occipital lobes about 1.4x the width of the lobe; light occipital spots restricted to the dorsum; mesostigmal plate flat and without projections; hind femora reaching the end of synthorax with 4-5 outer spines subequal in length, all of which are equal to or longer than the distance between their bases;

fore wings with R2 evenly curved beneath the pterostigma; pterostigmas similar in shape in both wings; single row of cells present distally of the pterostigmas on both wings; prenodal index > 1.25; ovipositor reaching to or slightly surpassing the end of tenth abdominal segment, ventral apical tip of the eighth abdominal segment angulated, blunt without a spine.

Diagnostis of *Pacificagrion* females (Fig. 6)

The distance between occipital lobes about 1.5x the width of the lobe; light occipital areas descending to the rear of the head; mesostigmal plate with horn-like projections at the inner corners; hind leg femora reaching the end of the synthorax with about 8 outer spines, some spines with length equal to approximately half the distance between their bases; fore wings with R2 descending to the wing margin in an obtuse angle with a slight kink beneath the pterostigma; pterostigmas dissimilar in shape: fore wing pterostigmas broad with almost equal sides, hind wings pterostigma elongated; double row of cells may be present distally from the pterostigmas on both wings; prenodal index ≤ 1.25; ovipositor broadly arched, not reaching the end of tenth abdominal segment, ventral apical tip of the eighth abdominal segment angulated with a weak blunt spine-like projection.

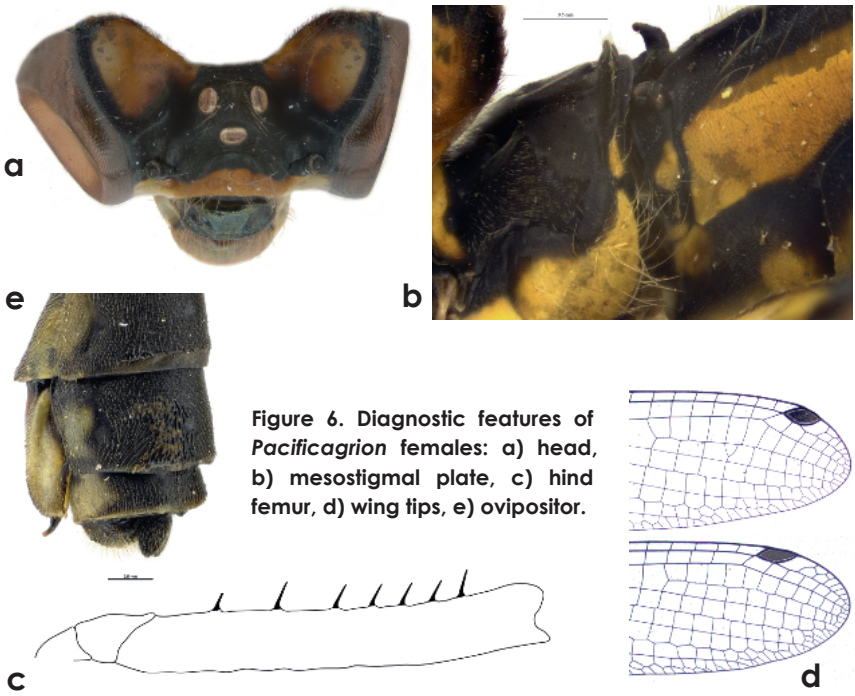

Figure 6. Diagnostic features of *Pacificagrion* females: a) head, b) mesostigmal plate, c) hind femur, d) wing tips, e) ovipositor.

Annotated faunistic checklist

All Odonata species observed are included below with information on their localities, taxonomic information that was found useful for future studies and general faunistic data.

Coenagrionidae

1. *Agriocnemis exsudans* Selys, 1877

Localities: 4-7, 9-10, 12, 32-33, 35-37, 40-42, 48, 50, 52, 57, 59, 63-65, 69, 70-71, 73-74, 82, 87, 90, 92, 94-95, 97, 101, 106, 108, 109, 111, 113-115, 121, 124, 126, 128, 130, 132

During the course of the study visual differences in the sizes were observed. Therefore specimens were taken from various locations for detailed examination in the laboratory. Table 2 presents the measurements of the body sizes of a total of 29 specimens collected from within the study area. The total body length varied within a range of 5.2 mm and 5.3 mm for females and males respectively. No further statistical tests or any other detailed measurements were performed to investigate the possible cause of the variation – such as habitat integrity, geographic location or season.

One larva collected from locality 88 and reared at the American Samoa Community College was provisionally identified as *A. interrupta*, however it may belong to *A. exsudans* (cf. the taxonomic discussion below).

A. exsudans was one of the most common species everywhere on the islands. It was present in a very wide range of habitats and in some occasions was the only Odonata species encountered in the sampled localities.

Widely distributed within the Samoan archipelago.

Table. 2. Body size variation in *Agriocnemis exsudans*.

Sex	Total body	Abdomen	Hind wing
female	22.4-27.6	17.7-21.9	11.6-13.8
male	22.7-28	18-22.3	10.7-13.5

2. *Amorphostigma armstrongi* Fraser, 1925

Localities: 1, 9-10, 14-16, 18, 25-27, 36

This is a common species on both Upolu and Savai'i islands. Fraser (1927) gives it for Tutuila as well, but this record must be verified. Donnelly (1986) reported on an undescribed *Amorphostigma* species from the same island which thus far is the only verified member of the genus on Tutuila (see below).

3. *Amorphostigma* sp. nov.

Localities: 48, 52, 55, 59-60, 62-64, 74

Donnelly (1986) recorded a new *Amorphostigma* from Tutuila Island, however the decription of this species is still pending. *Amorphostigma* specimens reported here are given with supposition as conspecific to what Donnelly (1986) claimed was an undescribed species inhabiting Tutuila Island. It was very common throughout the island and the sole representative of the genus established during the current study, but see the comments for the next taxa below.

4. *Amorphostigma* sp.
Localities: 48 (16 March), 92-95, 97-99, 101-104, 109-112
The third author (DP) established a significant amount of size variation, particularly in regard to body length, among the *Amorphostigma* populations on Tutuila Island. It is possible two species may be present on the island. One of these may be *A. armstrongi*, or alternatively may represent a second undescribed species.

5. *Ischnura aurora* (Brauer, 1865)
Localities: 4, 10, 15-16, 37-38, 41-42, 48 (16 March), 50-52, 54, 69, 71, 94, 113, 116, 121, 124, 133-134
Very common species within the whole archipelago. One larva was collected from locality 76 and reared at the American Samoa Community College supposedly belongs to this species as well.

6. *Pacificagrion lachrymosa* Fraser, 1926
Locality: 1 (02 July), 14
Fraser (1927) described the female of this species based on a single specimen which was found to be the largest known Samoan zygopteran at the time. The association with the male was based on the body size only and no comparisons with the holotype were made and nor were any illustrations provided.
The single female discovered during the present study agrees with Fraser's (1927) description and therefore was identified as *P. lachrymosa*. However,

Figure 7. Habitats for *Pacificagrion lachrymosa*: a) locality 1, b) locality 14 (the fifth author (FE) is shown catching *O. serapia*).

verification with field observations and association with males are needed because the body size seems to be disproportionally larger in the female compared to the male. Both specimens reported here were observed in similar habitats illustrated on Figure 7.

P. lachrymosa is endemic to Upolu Island.

7. *Pacificagrion* sp. nov.

Localities: 48 (16 March), 89

Pacificagrion spp. from Tutuila Island belong to an undescribed species reported in Donnelly (1986).

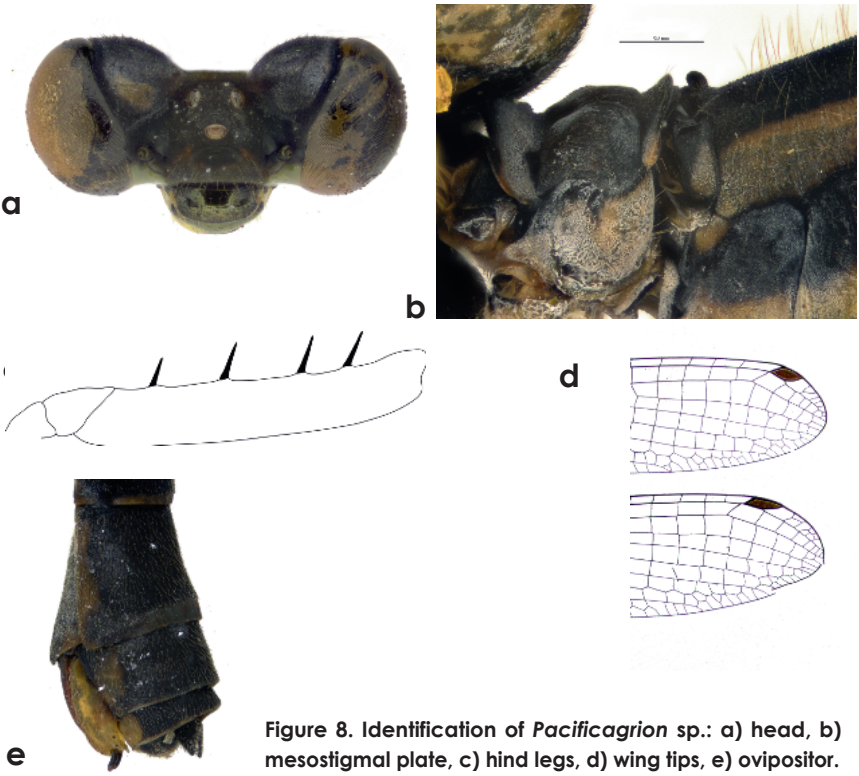

Figure 8. Identification of *Pacificagrion* sp.: a) head, b) mesostigmal plate, c) hind legs, d) wing tips, e) ovipositor.

8. *Pacificagrion* sp.

Locality: 25

Two females were identified as belonging to *Pacificagrion* although the characters used were not in full agreement with those established for the general habitus of the representatives from the genus. Figure 8 illustrates the body parts used for identification. Features close to *Pacificagrion* were: bulging occipital area of the head, horns on the mesostigmal plate, pterostigmas dis-

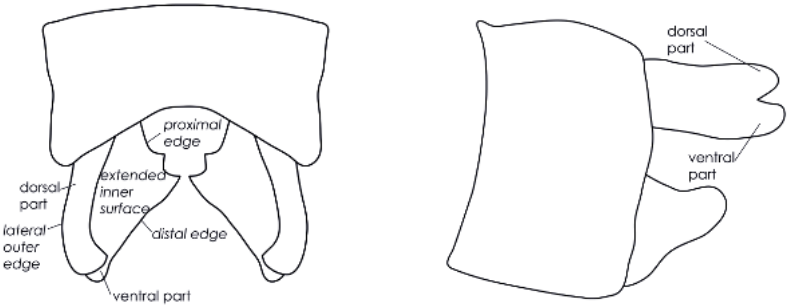

Figure 9. Generalised scheme of the abdominal tip of males in *Pseudagrion* with focus on superior appendages: a) dorsal view, b) lateral view.

similar, fore wings with R2 descending in an obtuse angle, two rows of cells distally from the pterostigmas, ovipositor short and stout, prenodal index 1.21. Features not in full congruence with the generic description given above include: hind leg stout and short, not reaching the end of the synthorax, with spines of the *Amorphostigma*-type and presence of a protrusion on the ventral apical tip of the eighth abdominal segment above the ovipositor.

9. *Pseudagrion samoense* Fraser, 1925

Localities: 4, 33, 37, 41

The Samoan *Pseudagrion* is morphologically very similar to its congenerics inhabiting other Pacific islands: *P. microcephalum microcephalum* (Solomon Islands), *P. m. stainbergerorum* (Tonga) and *P. pacificum* (Fiji). Figure 9 presents a generalised scheme of the shape of the male superior appendages of all four taxa. The inferior appendages were found less important for species separation. The main features investigated here for the superior appendages were: dorsal view – bulging dorsolateral outer edge and inwardly extended inner ventral surface with superficially triangular shape; lateral view – those dorsal and ventral parts were separated by an apical notch. Important characters that could be used for separation were found to be: dorsal view (ventral part only) – general shape (flat vs concave), distal edge (straight vs curved) and the teeth situated on the proximal edge (size and relative position to each other); lateral view – width and extension of the two lobes (dorsal and ventral) as well as the depth of the apical notch. A description of the modifications of all those features is provided below. There were small variations on every investigated feature, thus all characteristics for the individual taxa should be considered as generalised based on the most commonly observed morphological state. Also, some of the descriptions for the individual characters (like deep, large, more or less) make sense only in a direct comparison under microscope between specimens from various taxa and are non-descriptive if specimens from just one taxon are at hand. All characters were included in Table 3 which is compliment-

Table 3. Comparison between morphological characters of the Pacific *Pseudagrion* spp.

Trait	*P. m. microcephalum*	*P. m. stainbergerorum*	*P. pacificum*	*P. samoense*
Head				
spots on the postclypeus	joined in a thick transverse bar	separated	joined posteriorly	separated
black area behind lateral ocelli	thin with very small projections	thin with projections	interrupted behind the ocelli	excessive black area
blue occipital spots	large with projections	large with projections	large with projections	small without projections
Thorax				
synthorax	no black spot on the poststernum	black spot on the poststernum	no black spot on the poststernum	no black spot on the poststernum
Abdomen				
S2	no transverse bar on the basal dorsum; V-shaped mark not joined to posterior ring	transverse bar on the basal dorsum; V-shapd mark joined to posterior ring	no transverse bar on the basal dorsum; V-shaped mark joined to posterior ring	black spot on the basal dorsum; V-shaped mark joined to posterior ring
S3-9	spear-like marks on S3-4	spear-like marks on S3-4	no spear-like marks on S3-4	no spear-like marks on S3-4
S10	black could be reduced	black	black	black
secondary genitalia	black area around the hamules diffuses	black area around the hamules straight	black area around the hamules diffuses	black area around the hamules diffuses
Anal appendages (superior only)				
dorsal view (ventral part)				
inner surface	deeply concave	less concave	less concave	near flat
distal edge	curved	curved	curved	straigth
teeth (size)	small similar	distal larger	distal larger	large similar
teeth (position)	separate planes	same plane	same plane	same plane
teeth (direction)	up-turned	lateral	lateral	lateral
teeth (distance)	almost joined at the base	separated at the base	almost joined at the base	almost joined at the base
lateral view				
length	lower lobe longer	lower lobe longer	both lobes almost the same length	lower lobe longer
size	thinner	thicker	thicker	thinner
apical notch	shallow	shallow	deep	deep

ary to a similar comparison presented in Marinov (2012). Figures 10-11 illustrate these characters for all four taxa.

Dorsal view (inner surface of the ventral part of the superior appendages; Fig. 10): deeply concave only in *m. microcephalum*, less concave in *m. stainbergerorum* and *pacificum*, near flat in *samoense*; distal edge straight in *samoense*

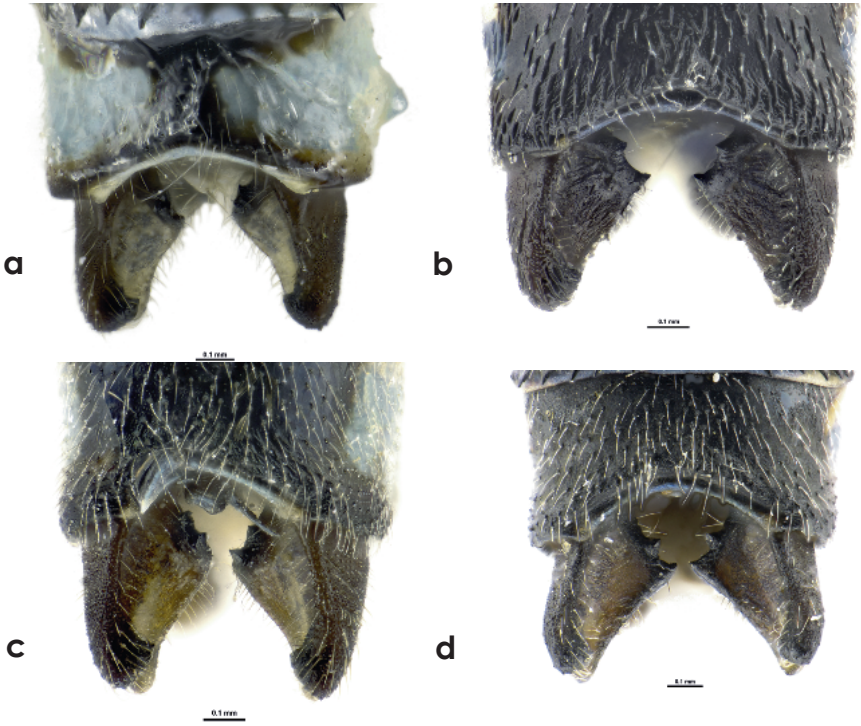

Figure 10. Comparison between shape of the ventral lobe of the superior appendages of Pacific *Pseudagrion* (dorsal view): a) *m. microcephalum*, b) *m. stainbergerorum*, c) *pacificum*, d) *samoense*.

and curved in the other taxa; two teeth on the proximal edge small and similar in size in *m. microcephalum*, large and of similar in size in *samoense*, distal larger than proximal in *m. stainbergerorum* and *pacificum*, the distance between them being larger in *m. stainbergerorum* while in other taxa they were found to be almost attached to each other with *m. microcephalum* only having the two teeth arranged one on the top of the other (in other taxa those were aligned in the same plane) and difficult to see from the dorsal view.

Lateral view (dorsal and ventral lobes of the superior appendages; Fig. 11): - ventral lobe always seemingly slightly larger than the dorsal, most pronounced in *samoense*; *m. microcephalum* and *m. stainbergerorum* indistinguishable, with both having shallower apical notch and thicker lobes compared to the other two taxa; *samoense* has the thinnest lobes of all four taxa with the ventral being narrower than the dorsal.

Body colouration provides additional diagnostic characters. The most important ones considered here were dorsal view of the head and abdomen with focus on the S10.

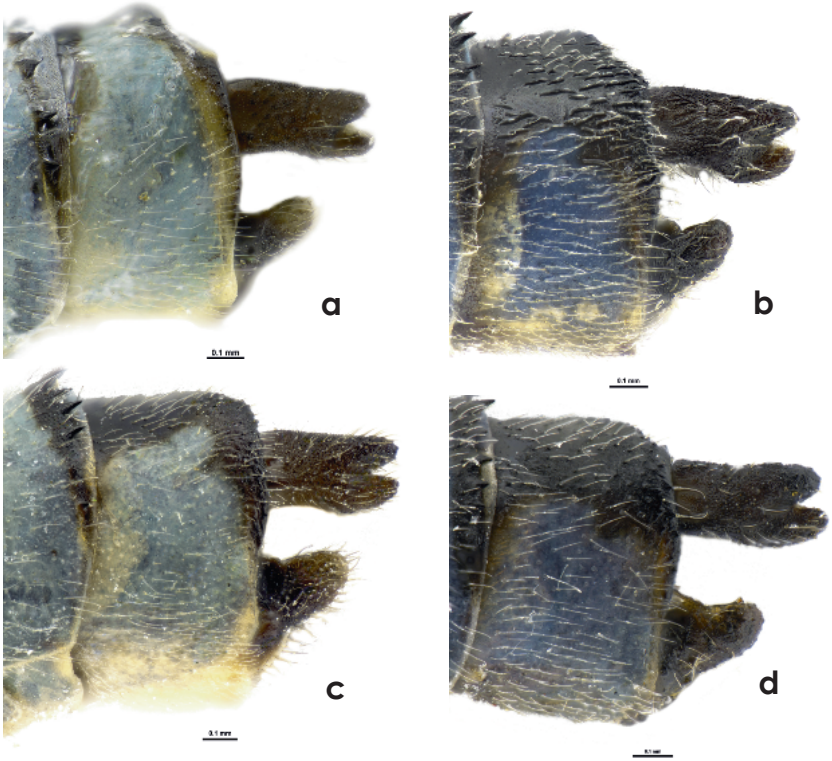

Figure 11. Comparison between the dorsal and ventral lobes of the superior appendages of Pacific *Pseudagrion* (lateral view): a) *m. microcepahlum*, b) *m. stainbergerorum*, c) *pacificum*, d) *samoense*.

Additional body characters from head (this study) and abdomen (from Marinov 2012a) are provided below for facilitating species identification.

Head (Fig. 12) – blue occipital spots smallest with roughly oval shape in *samoense* and larger superficially subtriangular shape in the other three taxa; those occipital spots with large lateral outer corners in *m. microcephalum* and *pacificum*, with minute to no corners in *m. stainbergerorum* and no corners in *samoense*; *pacificum* is the only taxon in which the blue area of those spots obviously continues on the rear occipital surface of the head; black posterior area developed strongly and descending in front of the median ocellus in *samoense* only, fully interrupted between lateral ocelli in *pacificum*, interrupted or not in *m. microcephalum* and not interrupted in *m. stainbergerorum*.

Abdomen (Fig. 13) – dorsal longitudinal black bands increase in size from very thin in *m. microcephalum* to almost completely dark on S3-7 in *samoense*; *pacificum* and *m. stainbergerorum* are in between the two extremes, with *paci-*

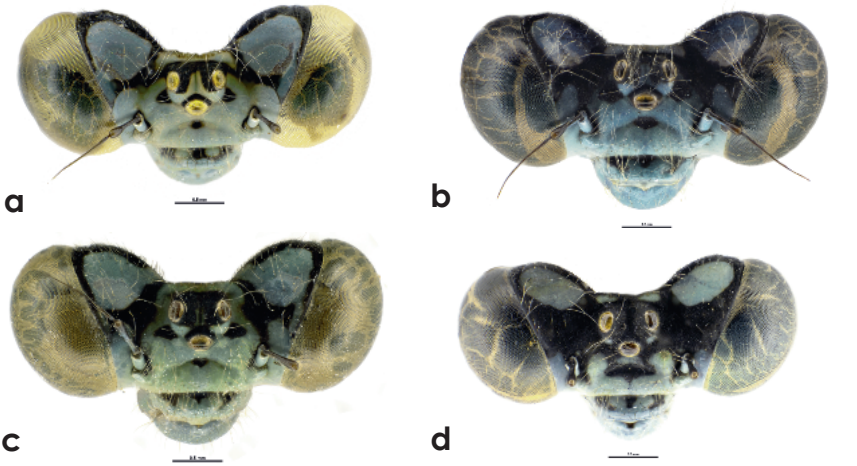

Figure 12. Comparison between the heads of Pacific *Pseudagrion* (dorsal view): a) *m. microcepahlum*, b) *m. stainbergerorum*, c) *pacificum*, d) *samoense*.

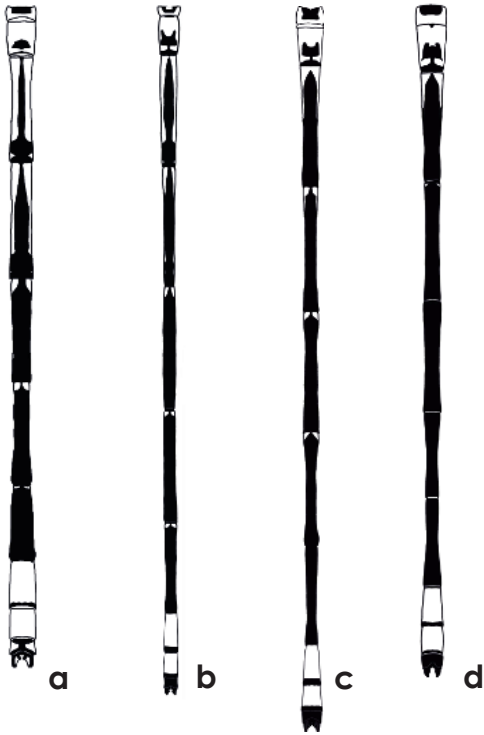

Figure 13. Comparison between the abdomens of Pacific *Pseudagrion* (dorsal view): a) *m. microcepahlum*, b) *m. stainbergerorum*, c) *pacificum*, d) *samoense*.

ficum having approximately the same pattern as *m. microcephalum*; S7 entirely dark on the dorsum in *samoense* only, while the other three taxa have blue basal spots; S10 dark area on the dorsum as a thin bar in *m. microcephalum*, almost fully occupying the surface leaving for small blue lateral spots in *pacificum* and completely dark in *m. stainbergerorum* and *samoense* (one specimen with blue pattern only).

P. samoense has been previously reported for Upolu Island only. It is now recorded on Savai'i Island as well.

Aeshnidae

10. *Anaciaeschna jaspidea* (Burmeister, 1839)

Localities: 51, 125

One male collected from locality 51 is illustrated on Figure 14 and is compared to specimens presented in Marinov et al. (2013a): *A. jaspidea* from Samoa and Tonga in comparison to *A. melanostoma* Lieftinck, 1949 from the Solomon Islands. *A. melanostoma* is included only with the original drawings of the male anal appendages as it was unavailable for investigation.

The important characters considered here were the colouration of the frons and shape of the anal appendages. Note that the dark area on the frons varies from none (Tonga), small band on the top (here reported male) to continuous, but diffused on postclypeus (Samoa). The superior appendages are nearly identical in all specimens. The only small difference was the length of the bases when observed from various angles. Rotating the appendages and looking at them from the dorso-lateral view they appear short in the specimen from Tonga, but are equal in length in the Samoan *jaspidea* and Solomon Islands *melanostoma*.

The male specimen reported here was collected from locality 51 in the early afternoon on a bright sunny day. It was passing through the locality and thus considered as an accidental species there. Another male sighted at locality 42 on Savai'i Island was identified as possibly *jaspidea*, but was not collected to confirm the correct identification.

Previously reported for Upolu and Savai'i only. Now found on Tutuila Island.

11. *Anax guttatus* (Burmeister, 1839)

Localities: 7, 69, 85-86, 116, 124

Anax was detected at Lake Lanoto'o, but neither collected for examination in hand nor observed perched to check for diagnostic features from a distance. The lake is situated above 700 m and following Donnelly's (1986) distribution scheme it must have been *A. gibbosulus* Rambur, 1842 that occurs high up in the mountain. Moreover the same species has already been reported for this locality (Donnelly 1986). However, whether *A. gibbosulus* still occurs in Lake Lanoto'o remains to be verified by future studies.

Previously reported for Upolu and Savai'i only. Now recorded on Tutuila and Aunu'u.

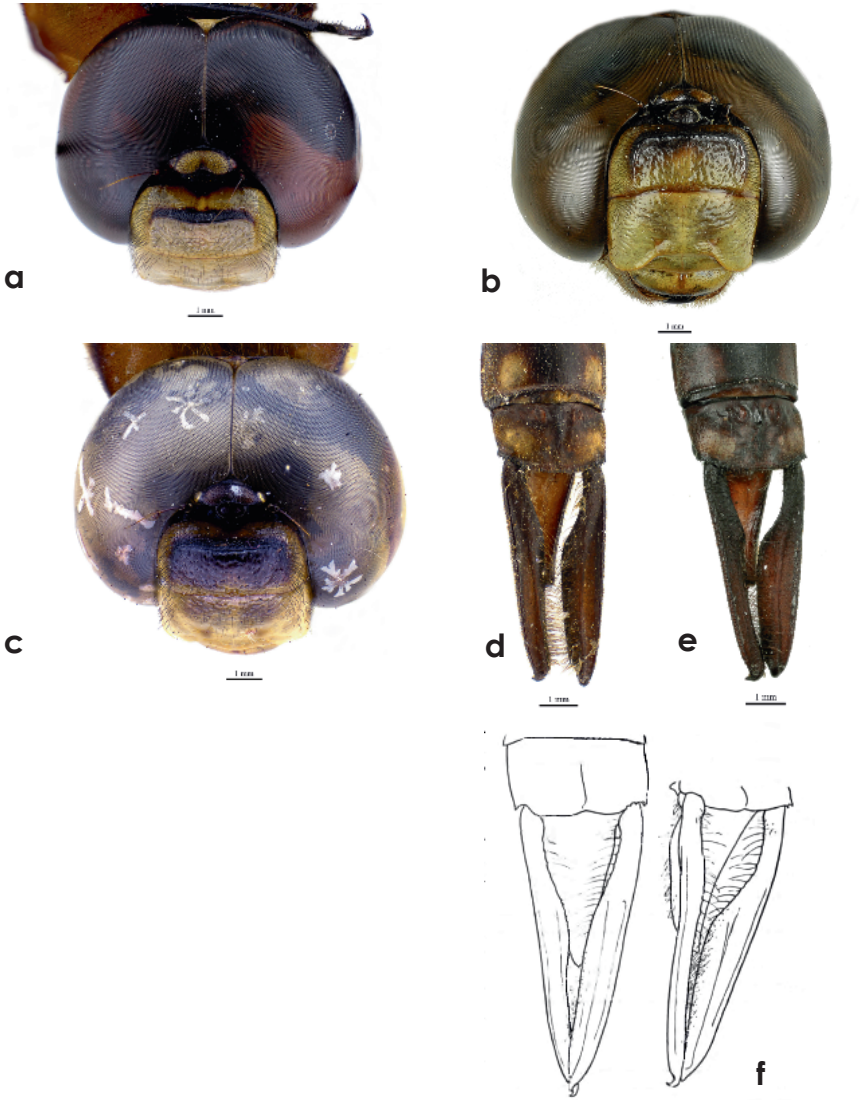

Figure 14. Comparison between *Anaciaeschna jaspidea* (from Tonga and Samoa) and *A. melanostoma* (from Solomon Islands): a) Tonga, b) Samoa (this paper), c) Samoa (Marinov et al. 2013a), d) Tonga, e) Samoa (this paper), f) Solomon Islands.

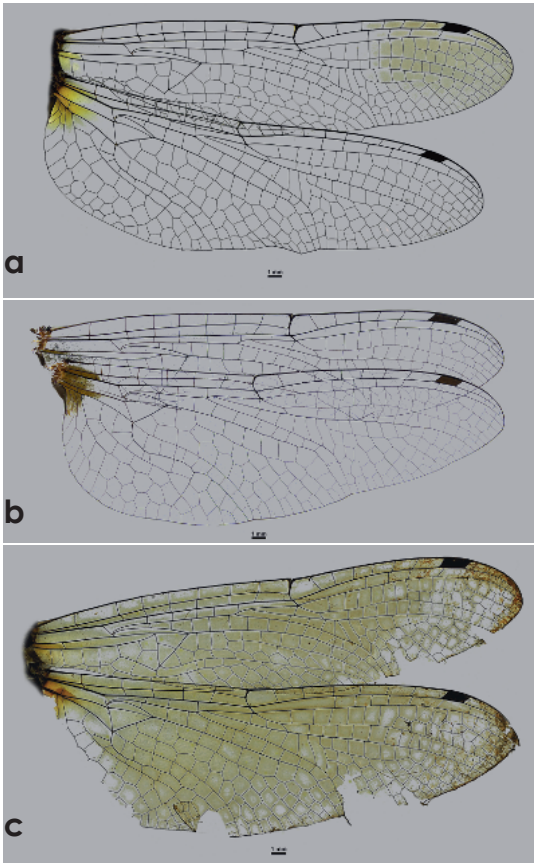

Figure 15. Wing pattern of female *Hemicordulia hilaris*: a) yellow apical spot on the fore wings only, b) transparent wings in young specimens, c) yellow wing surface in old specimens.

12. *Anax* sp.
Localities: 4, 33, 36, 41-42, 71, 121, 122 (09 July)
These localities are for eye-sighted *Anax*-looking individuals which were not collected to confirm the correct species affiliation. They were identified as presumably *guttatus* based on the distribution on the Pacific islands given by Donnelly (1986) for the closely related *A. guttatus* and *A. gibbosulus* lowland areas for the first and mountain regions for the second.

Corduliidae
13. *Hemicordulia hilaris* Lieftinck, 1975
Localities: 20, 25-26, 69 (18 July), 90-91

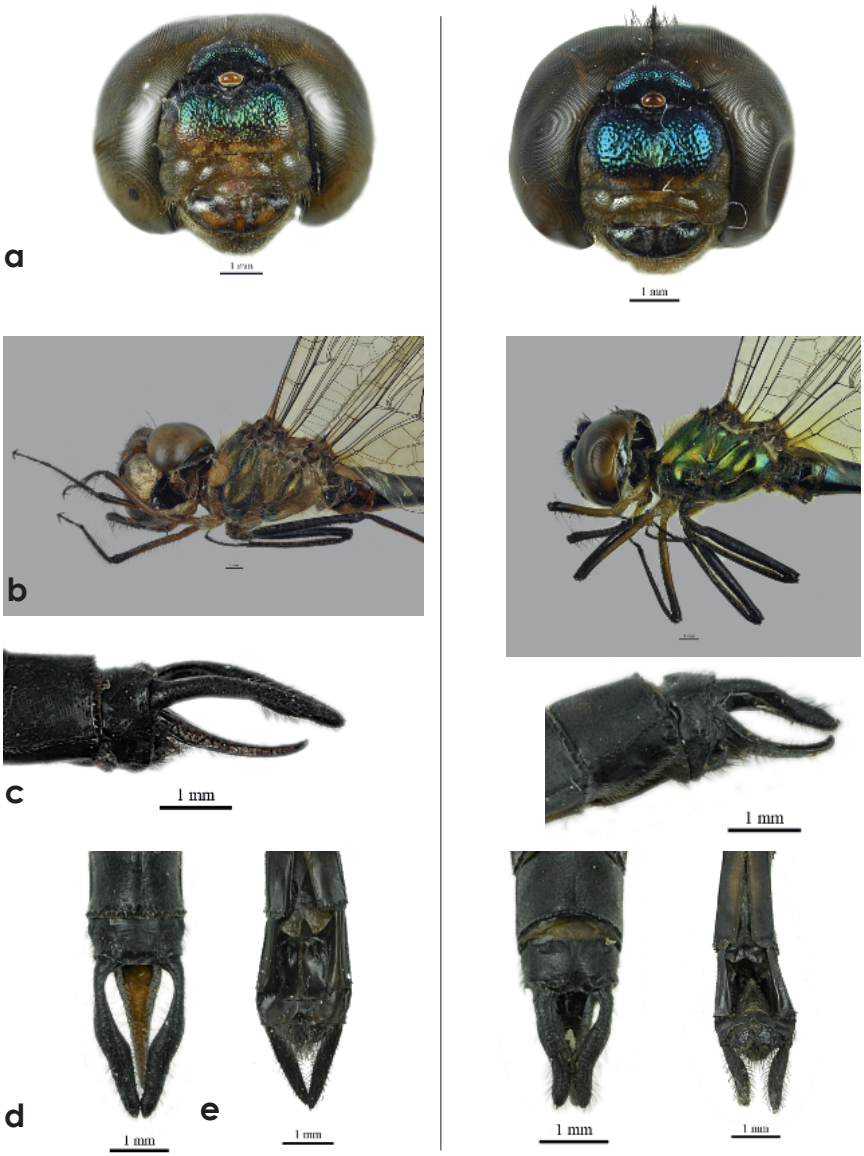

Figure 16. Comparison between body parts of Samoan *Hemicordulia* spp.: a) head, b) thorax, c) male appendages lateral view, d) male appendages dorsal view, e) female vulval scale. Left column: *H. hilaris* Right column: *H. pacifica*

Figure 15a illustrates the wing pattern of a young female *H. hilaris* which has not been recorded before. It differs from the transparent wing area typical of young specimens (Fig. 15b) and opaque wings of old females (Fig. 15c).
H. hilaris was recorded only as an accidental species from all localities where it was observed during the present study. Adults either flew alongside the tourist tracks high above any aquatic habitats or were flying low over the taro plantations close to wetlands. No breeding activity was recorded. It was not encountered in the sites when they were revisited and it is unclear as to what might be a suitable habitat for the species.
Reported for Upolu and Tutuila islands only.

14. *Hemicordulia pacifica* Fraser, 1925

Localities: 9, 36, 48, 52, 55-58, 60, 62, 64 (14 July), 69-70, 73, 80, 92-104, 106-108

This species has never been illustrated before. Fraser (1925) provided a detailed description, but no figures. Therefore we present here some illustrations of important diagnostic features that may be used to distinguish *H. pacifica* from its congenerics. A morphological comparison to *H. hilaris* is provided below because this is the other common species from the same genus all over the Samoan archipelago.
Generally the two species could be distinguished in the field by their sizes. Males of *H. pacifica* have very small delicate bodies. Females of the same species appear to be larger than males and can be mistaken for *H. hilaris* in the field. However, when examined with a hand lens, there are several characters that may help distinguish them.
Figure 16 compares the two *Hemicordulia* collected during the present study. They can be reliably distinguished by:

- labrum: yellow area in hilaris, dark in pacifica (Fig. 16a);
- thorax: hairy green and opaque yellow in *hilaris*, less hairy and almost completely metallic green in pacifica (Fig. 16b);
- male appendages lateral view: superior longer than inferior in *hilaris*, both subequal in length in *pacifica* (Fig. 16c);
- male appendages dorsal view: superior gradually converging to a point where they touch with their tips in *hilaris*, converge distally and run parallel sided for about one third of their length in *pacifica* (Fig. 16d);
- female vulvar scale: deeply notched with oblique to near parallel sides in *hilaris*, deeply notched with strongly oblique sides meeting at an obtuse angle in *pacifica* (Fig. 16e).

Figure 17 illustrates the wing venation in H. pacifica. It was not found to be a useful diagnostic as the general arrangement of the veins is similar to that of *H. hilaris*. The differences were observed in the sizes and number of the pre- and postnodal cross veins. Being larger, *H. hilaris* tend to have bigger wings and more cross veins. No further investigations were carried out to document the variation in those two characters.

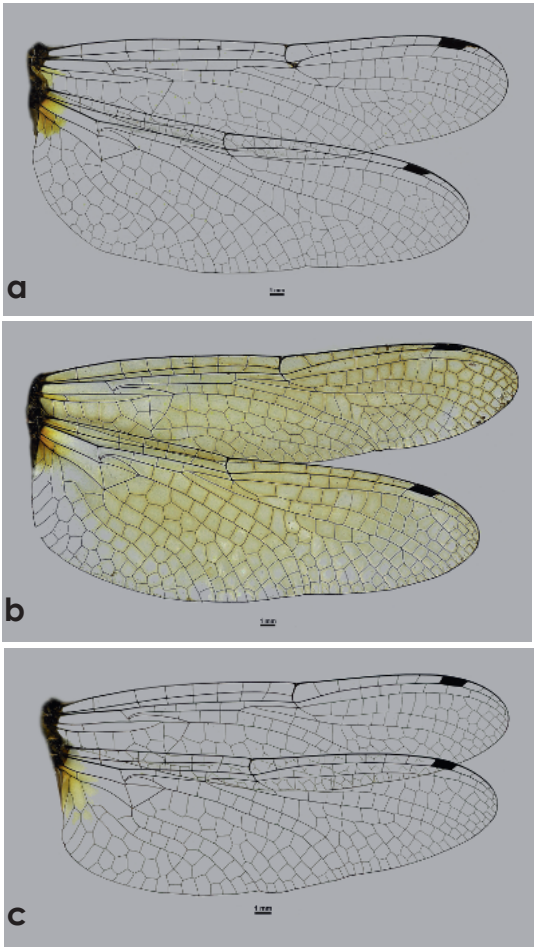

Figure 17. Wing venation in *Hemicordulia pacifica*: a) young female, b) mature female, c) male.

H. pacifica was one of the most common species encountered during the present study and far more common than *H. hilaris*. It was observed in a variety of habitats ranging from roadside canals and ditches to forested streams and seepages. Adults can easily be spotted from the road (especially on Tutuila Island) where trickling water flows down the hill and makes small puddles. Males fly close above the water surface returning continuously to a selected area which is usually the border zone between sunny places and shadow from the surrounding trees. Ovipositing females were encountered laying eggs unguarded. They chose very shallow water and deposited eggs on the mud substrate. Those were always shady parts of the stream on one occasion situated in a very densely vegetated area. Trees and tall bushes

seemed to be the favourite sites for teneral individuals.
Reported for Upolu and Tutuila islands. Now found on Savai'i Island.

15. *Hemicordulia* sp.

Locality: 2 (02 July), 11

One large *Hemicordulia*-like individual was observed in locality 2, but not collected for further identification. It had a dark body with blue to deep purple iridescence. It was larger than the other two *Hemicordulia* encountered during the present study and was provisionally identified as *H. cupricolor* which is the only other representative from the genus known from the Samoan archipelago. Unlike the other two *Hemicordulia* this individual did not stay at the

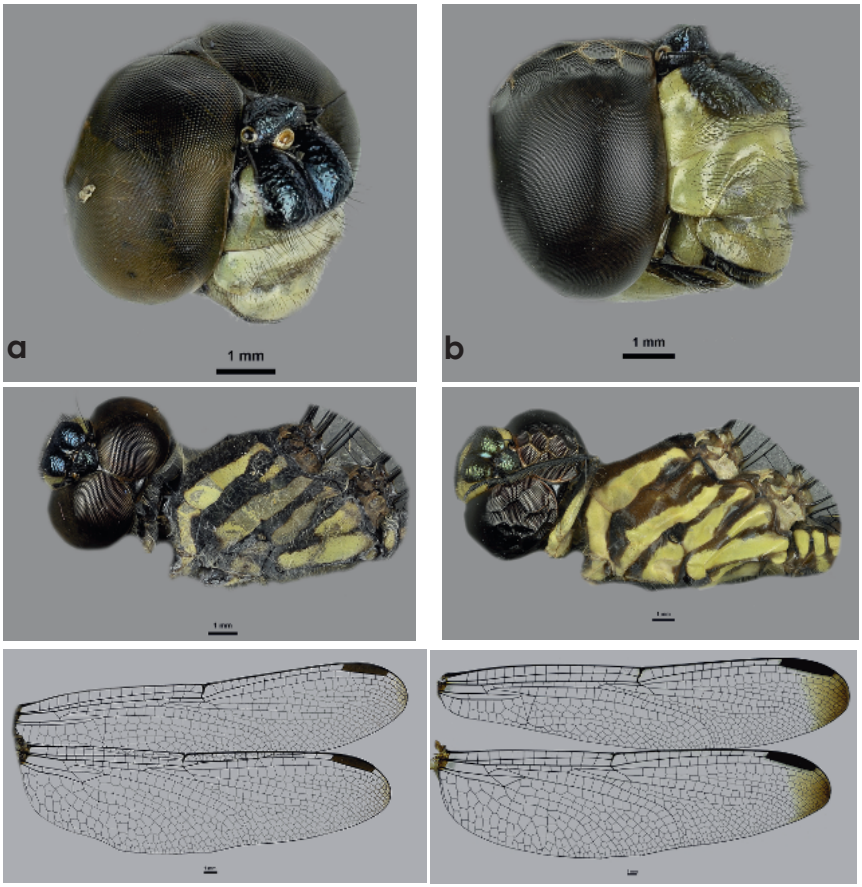

Figure 18. Comparison between the body morphology of *Lathrecista asiatica* sampled from: a) Samoa, b) Fiji and Tonga (represented with one specimen because no differences were observed between these two islands).

site for long and left after three-four swift flights. It was not encountered again at the same spot.

Another individual was briefly spotted at locality 11.

Libellulidae

16. *Diplacodes bipunctata* (Brauer, 1865)

Localities: 7, 13, 16, 22, 25-27, 32-33, 41, 50-51, 54-55, 59, 62, 64 (14 July), 68 (14 July), 69-71, 73-75, 77-78, 83, 90, 92, 94, 96, 108, 113, 116, 120-121, 122 (09 July), 124, 127-128, 132

Widely distributed within the Samoan archipelago.

Table 4. Morphological characteristics of *Lathrecista asiatica* specimens collected from Samoa compared to conspecifics from Fiji and Tonga.

Trait	Samoa	Fiji-Tonga
dark line along the eye	present	absent
Y-shaped thoracic mark	deep	shallow
dark line across metepimeron	interrupted	complete
dark spot at the tip of the wings	vestigial	well developed

17. *Lathrecista asiatica* (Fabricius, 1798)

Localities: 32, 51, 69, 81, 84, 106, 108, 111, 118-119, 128, 131

Samoan specimens collected during the present study were compared to conspecifics reported in Marinov (2011, 2012a) for Fiji and Tonga respectively. They all agreed with the description of the nominate subspecies in almost every respect except the body size. Measurements given in Ris (1909-1919) for *L. a. asiatica* (abdomen 28-32 mm; hind wing 35-38 mm) were consistent with those taken on specimens from Fiji and Tonga, while Samoan specimens were smaller (abdomen 24-27 mm; hind wing 28-31 mm) and possessed other morphological characters that differed from their relatives from other Pacific islands (Fig. 18). The most important differences are included in Table 4.

Previously reported for Upolu and Savai'i islands only. Now also for Tutuila and Ofu islands.

18. *Macrodiplax cora* (Kaup in Brauer, 1867)

Localities: 22, 92, 124 (19 July)

The two males collected/observed during the present study in localities 22 and 92 were accidental visitors to the localities. The Aunu'u Island site was visited twice with at least three hours spent on both occasions. The collected specimen was the only one observed during the whole period. Therefore no information about the preferred habitat or any behaviour notes can be provided here.

Reported for Upolu Island only. Now also recorded for Tutuila and Aunu'u Island.

19. *Orthetrum serapia* Watson, 1984

Locality: 14

O. serapia was surely confirmed for Upolu (one male collected and released at the site), but on Savai'i only flying individuals were observed in localities 41-42. They were provisionally identified as *O. serapia* because of the predominance of the records on this species from Tonga and Fiji (Marinov 2012a, 2013; Marinov & Sakiti-Waqa 2013) where it is so far the only species from the genus established for sure, however not included here because verification is needed.

The three localities investigated during the present study differ considerably – two wetlands situated close to the coast on Savai'i and a mountain stream

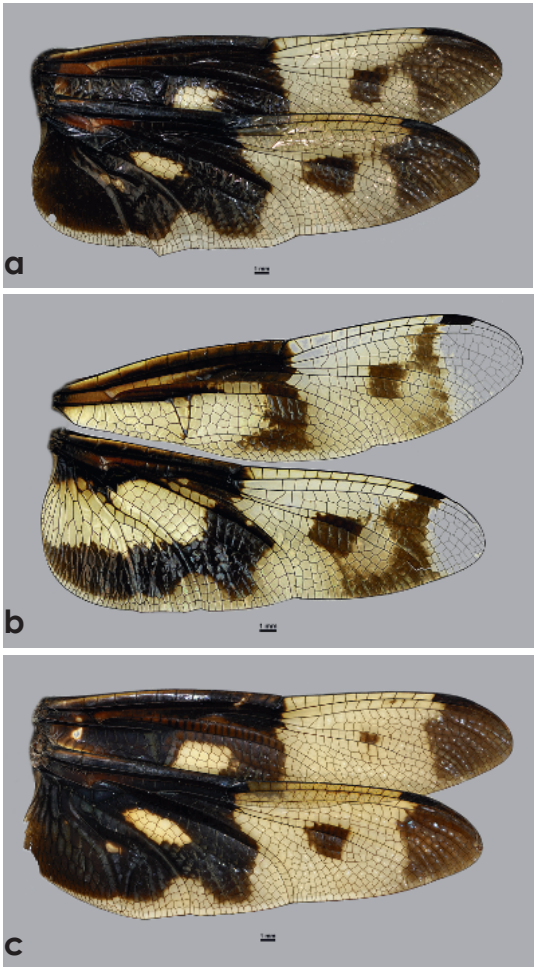

Figure 19. Wing colouration of *Rhyothemis regia chalcoptilon*: a) male (common colouration with bridge between central spot and apical dark area), b) female, c) male (uncommon colouration with the central spot and apical dark area separated).

on Upolu. In the first instance the observed individuals were identified as probably breeding because of the number of males performing territory defending behaviours. The Upolu observation was of a single male that selected perching sites near the stream. It was regarded as accidental to this area, however breeding in small streams is to be expected for *O. serapia* as it does so in other parts of its range (Marinov & Pikacha 2013).
Reported only for Upolu and Savai'i as *O. sabina* (Drury, 1770).

20. *Pantala flavescens* (Fabricius, 1798)
Localities: 8, 10, 16, 19, 32, 41-43, 49-51, 54, 56, 69-71, 73, 78, 91-92, 105, 107-108, 111, 116-117, 121, 124

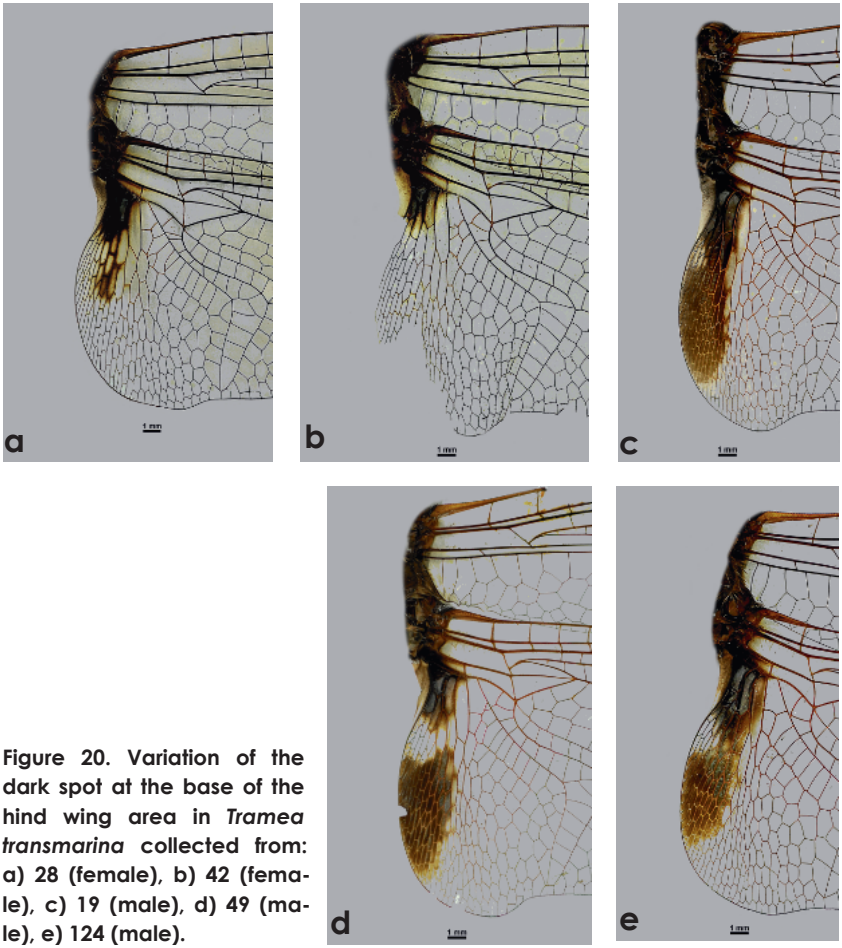

Figure 20. Variation of the dark spot at the base of the hind wing area in *Tramea transmarina* collected from: a) 28 (female), b) 42 (female), c) 19 (male), d) 49 (male), e) 124 (male).

Figure 21. Comparison of the body colouration in *Tramea transmarina*: a) New Caledonia, b) Samoa (same pattern typical of specimens collected from Fiji and Tonga).

Generally very common species all over the study area. It is usually one of the first species that one will encounter when visiting any of the Pacific islands. However, *P. flavescens* was not observed on Ofu and Olosega islands although the coastal area of the first was walked for its whole length on the southern side.
Widely distributed within the Samoan archipelago.

21. *Rhyothemis regia chalcoptilon* Brauer, 1867
Localities: 1 (02 July), 4, 17, 32-33, 41-42, 51, 68 (14 July), 69-70, 73, 121, 124
The sampled specimens show no great variations in the wing colour pattern from the images provided in Lieftinck (1959, 1962). The commonest form was the one in which the central wing spot on both wings connects to the dark apical area (Fig. 19a, b). One specimen only had those spots separated (Fig. 19c) similar to that illustrated in Lieftinck (1962) for Saipan, Mariana Islands. This specimen came from Aunu'u Island where the commoner form was also collected (Fig. 19a). The only female collected during the present study fits well with the description of the light colour form of the subspecies (Fig. 19b) illustrated also in Lieftinck (1959).
This species is an inhabitant of stagnant water bodies. During the day adults stay inside the wetland where they select plant stems as perches. They are amongst the first species active early in the day and some of the last to disappear from the area on overcast or rainy days.
Widely distributed within the Samoan archipelago.

22. *Tholymis tillarga* (Fabricius, 1798)
Localities: 1 (02 July), 7, 12, 39-40, 79, 105, 116, 121, 124
Widely distributed within the Samoan archipelago.

23. *Tramea transmarina* Brauer, 1867
Localities: 3, 19, 28, 32, 41-42, 49, 70-71, 77, 105, 121, 124, 128
Male specimens collected during the present study were compared to conspecifics obtained from New Caledonia, Fiji and Tonga. They were identical in their overall body proportions as well as morphology of secondary genitalia and anal appendages. The dark area at the base of the hind wings varied enough to be considered as important diagnostically (Fig. 20). However, New Caledonian specimens possessed some morphological characteristics that differentiate them from specimens from other Pacific archipelagos. Figure 21 illustrates some notable differences in the body colouration. New Caledonian specimens differed from the rest by having a generally brighter appearance: lighter yellow labium with reduced to almost lacking black on the lateral lobes; labrum dark only in the middle; purple on the dorsum of the head reduced; dark thoracic spots and bands less intense; dorsal black spots on S8-9 in lateral view do not extend ventrad, and bases of superior appendages bright red.
Females were not compared because they are usually harder to find and no material from other Pacific islands was available. Only two specimens were encountered during the present study.
Reported for Upolu and Savai'i islands. Now also for Tutuila and Ofu islands.

Figure 22. Lava field on the northern part of Savai'i Island.

Figure 23. Water tank in Malololelei.

Discussion

Marinov et al. (2013a) provided a revised and updated checklist of the Odonata fauna of the Samoan archipelago, including 30 species from the main islands of Upolu, Savai'i and Tutuila and the first record of Odonata from Aunu'u Island. They outlined important knowledge gaps and proposed areas for further research. *Diplacodes trivialis* (Rambur, 1842) has to be removed from their list. It was included based on the information presented in Dommanget & Mashaal (2000), however it is now clear this record was wrong (cf. Marinov et al. in prep.), and for the moment the easternmost range of *D. trivialis* must considered to be Lau Islands, Fiji (Marinov & Waqa-Sakiti, 2013).

Samoan Odonata are a very intriguing taxonomic puzzle. The foundations of the studies were laid down by Brauer (1867a, b), but Fraser's inspirational work in the mid-

twenties was considered to be the milestone of the odonatological research of this Pacific archipelago (Marinov et al. 2013). Fraser received specimens for identification collected by the New Zealand medical practitioner Dr John Armstrong who was a famous entomologist too (Corbet 1978). The collections of Odonata were combined with descriptions of colouration of the live individuals, but little was given on the localities and the type of habitats where dragonflies were found.

Odonata habitats in the Samoan archipelago

Fraser (1925) claimed that he could only guess what the sampling site might have looked like judging from the ecological specialisation of the specimens from other parts of their range or from the close allies of the Samoan endemics.

Donnelly (1986) gave the first account of general freshwater habitat availability and suitability for Odonata species for the whole archipelago. He emphasised that Savai'i tends to have limited surface water. Most of the rain that falls passes quickly through porous, cracked lava flows of which recent activity can still be seen on the northern part of the island (Fig. 22). Streams are ephemeral and hold water all year round only at lower elevations. Pond habitats for Odonata on Savai'i and Upolu occur at higher elevations and most of them are difficult to access. The much smaller and highly-eroded Tutuila Island has abundant stream and seepage habitats suitable for lotic Odonata species. Lentic habitats on Tutuila, Ofu and Olosega are restricted to coastal wetlands most of which are highly influenced by the tide and thus devoid of Odonata species.

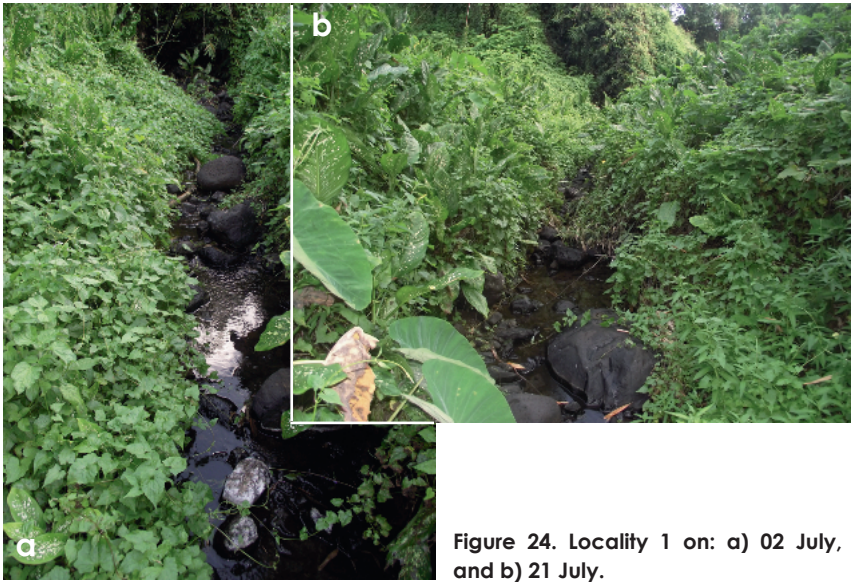

Figure 24. Locality 1 on: a) 02 July, and b) 21 July.

Unfortunately no historical records were kept on Odonata habitats to see how they have changed for the time after Armstrong had collected intensively, mainly within the vicinity of Apia. Moreover, some of his localities are difficult to locate on contemporary maps or following inquiries with local people. With no coordinates provided, one may wonder where exactly is the type locality of *Pacificagrion dolorosa* Fraser, 1953 given as Hellesoi's paddock or how to find the last known locality of *Agriocnemis interrupta* Fraser, 1927 reported as "An overgrown bog-hole full of water ... formed by an American tank which had become bogged when attempting to cross

Figure 25. Freshwater crayfish/prawns in a puddle on Tutuila Island.

the island" (Fraser 1927). During the current study a special visit was paid to Malololelei, which is one of the most often cited Odonata localities and type locality of *A. interrupta, Ischnura buxton*i Fraser, 1927, *I. haemastigma* Fraser, 1927, *I. albistigma* Fraser, 1927, *and Amorphostigma auricolor* Fraser, 1927. Unfortunately the precise location was not found. The area looked absolutely not suitable for dragonflies, and according to the villagers it had never had any sort of running or stagnant water resource available to the village. Nowadays people have their own water tanks (Fig. 23) to cope with the drought within the vicinity of their village. Malololelei is situated on a steep slope at about 747 m a.s.l. with a main island crossing road passing through it. However, there are secondary roads leading eastwards to a steep valley which is possibly the way to the mountain gullies where Buxton (1930-1935) claimed it was easy to collect insects from two ravines situated at about 2,000 ft (610 m) a.s.l. From the accompanying photos (cf. Buxton 1930) these appear to be substantial streams with pools and torrents

Figure 26. *Rhyothemis regia chalcoptilon*.

Figure 27. Taro plantation on Aunu'u Island – a habitat for nine Odonata species.

which need to be precisely located and investigated all year around. The hydrology regime of those sources is important and it is necessary to to establish if they dry up completely at certain periods or support water permanently.

Drying up of aquatic habitats is a very interesting phenomenon observed even during the senior author's short visit to the islands. Figure 24 presents two views of the same locality 1 taken within 20 days. The drought had altered the hydrology of almost all localities on Savai'i Island visited at about 50-60 m a.s.l. Those still with water flowing down from the hills were very turbulent with muddy water or had just a few puddles hidden under the shadow of the trees. Larger rivers like the one running by the village of Sili (locality 37) looked promising for exploration, but a visit to the upper course of the river and its tributaries should have been arranged in advance with the landowners.

As Donnelly (1986) pointed out for the first time, freshwater crayfish introduced into the rivers might also have some effect on the abundance of Odonata. They were present on Tutuila Island even in the puddles formed along the roadside ditches by the seepage water running through them (Fig. 25). Crayfish (or prawns) were easily spotted in locality 34 on Savai'i Island where no dragonflies were observed. On the other hand they were also abundant in one of the richest sites visited during the present study – locality 1 on Upolu Island.

Donnelly (1986) also felt that the time of the year should not influence sampling success, because specimens reported in Fraser's studies were collected all year round. However, the season might have an observable effect should a more detailed sampling scheme be performed. The water fluctuations of the streams probably result in shift of the Odonata community composition and abundance. Hot days during the dry season, as experienced during the present study, resulted in less Odonata species diversity from a locality on Aunu'u Island when revisited within ten days. In the highest heat of the day only male *R. p. chalcoptilion* (Fig. 26) remained active within the canals around the taro plantations (Fig. 27). They often perched in obelisk position which is known to reduce to heat absorption. Male *A. exsudans* were also found in large numbers during a hot day, and many of them had a whitish powder-like substance at their abdominal tips which is an unusual feature for the normally completely black dorsal surface. The nature of this colouration was unclear as was the reason for its appearance. Whether this sort of powder builds up as a physiological reaction to ease the effect of the heat is something that must be explored further.

The potential for seasonality of the Samoan species should not be disregarded. In his publications Fraser mostly gave the sample period with dates, but did not specify the number of specimens taken or observed on each date. For example, 16 male and four female *I. haemastigma* were collected between August-November 1951 which outlines a period when the species could possibly be seen. However, sample dates in October dominate, which implies that this could be the more likely time of the year to encounter *I. haemastigma*, and possibly other ishnurids, in the field. If seasonality does play a role in species' phenology, August specimens could be just

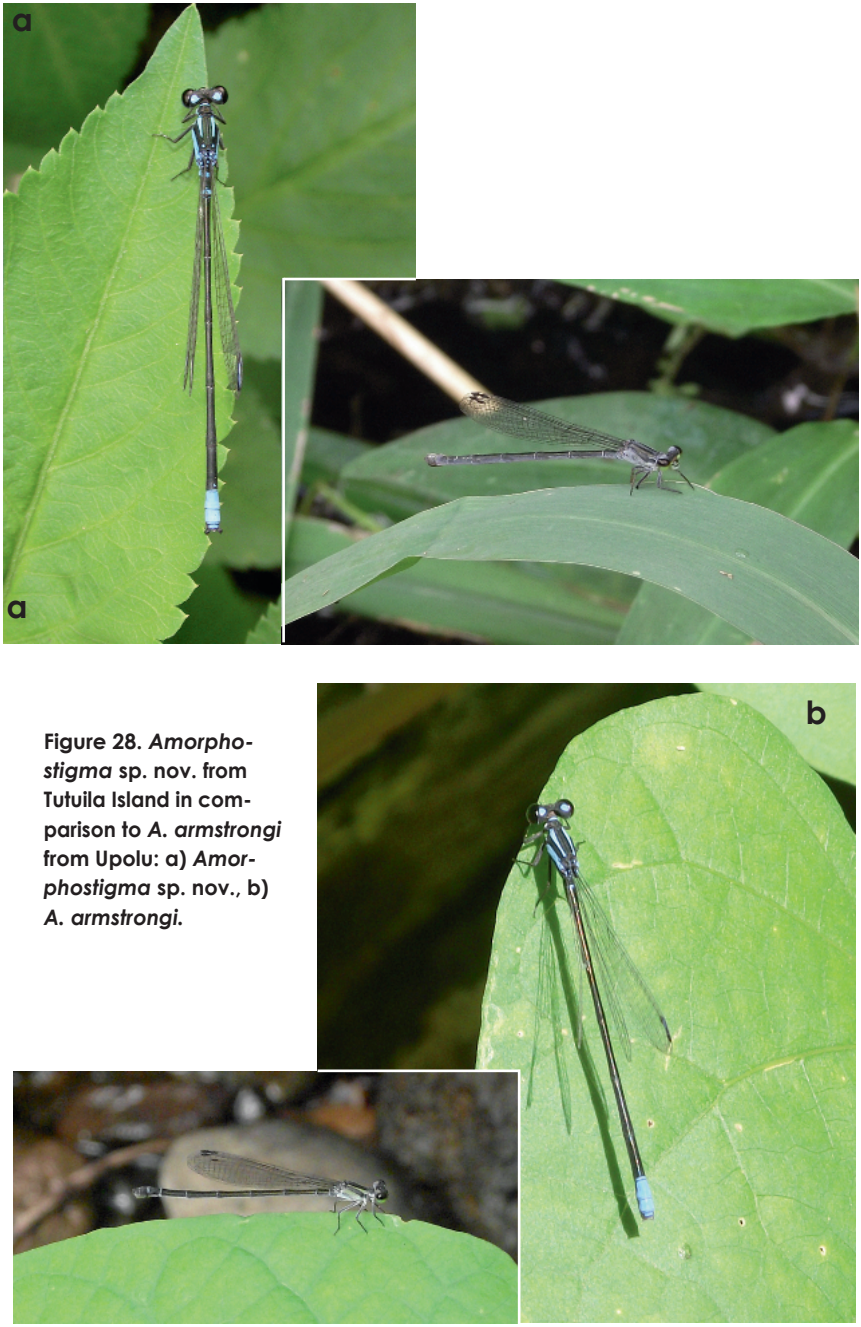

Figure 28. ***Amorphostigma*** **sp. nov. from Tutuila Island in comparison to** ***A. armstrongi*** **from Upolu: a)** ***Amorphostigma*** **sp. nov., b)** ***A. armstrongi.***

Figure 29. Locality 48 – type locality of two undescribed species from *Amorphostigma* and *Pacificagrion* genera.

accidental early season records. At the same time Fraser (1927) reported on two male and seven female *I. buxtonii* sampled on 24 July 1924, which suggested that *Ischnura* species did fly earlier in those times. However, Fraser (1953) decided that those seven females actually belonged to *A. armstrongi*, which was found to be very common in July during our study.

The climate of Samoa was discussed in detail by Buxton (1930), who notes that the months of May to August inclusive are much drier than others, at least at Apia, with only 16 percent of the total annual rainfall occurring during this period. This in turn

Figure 30. Faimulivai Marsh on Aunu'u Island: a) general view of the marsh, b) overgrown water surface.

seems to have an effect on the phenology of aquatic insect adult emergence, including Odonata. Similar to the observations above, it is the experience of the third author (DP) that Odonata on Tutuila are far less abundant during survey work undertaken in the dry months of August and September than in the wetter month of March.

Possible effects of habitat degradation on the odonate fauna cannot be assessed as we lack historic evidence of what the freshwater resources might have looked like 80-90 years ago. Donnelly (1986) did not believe the alteration of habitat to be an important cause of the absence of some species at the time of his visit. He failed to find most of the endemic *Ischnura* species and discovered only *I. chromostigma* on Tutuila Island together with two undescribed species from *Amorphostigma* (Fig. 28) and *Pacificagrion* genera. The current study had even less success as no endemic *Ischnura* were encountered and the new *Pacificagrion* on Tutuila was not found either. Generally the sites visited were very poor in any Odonata species. Locality 48 on Tutuila Island (Fig. 29) known as the locality for two undescribed species from genera *Amorphostigma* and *Pacificagrion* was visited on three different days during this study. Various times and day light conditions were chosen in order to investigate the daily activity. In one occasion four hours were spent at a single spot observing an area of about 50 *m.* All together three species were observed, only represented by very rare sightings of flying individuals. Other streams on the same island did not produce any Odonata individual at all even though they were traced for a much longer distance than described in the Methods section. This was true for both completely and partly shaded habitats and was also established for most of the streams on the other two main islands – Upolu and Savai'i. In general completely shaded streams are avoided by Odonata and in the rare sightings of dragonflies individuals usually preferred parts of the habitat that were partly sunlit. *H. pacifica* was seen on one shady stream, but only passing individuals. *Amorphostigma* sp. nov. was also seen, but only one individual in more than 300 meters walking distance.

Habitat alteration was contemplated amongst the other reasons for the poor success in locating Odonata during the current study. Natural succession has led to the open water surface of Faimulivai Marsh on Aunu'u Island being almost completely overtaken by vegetation producing a strong mat that one could walk on (Fig. 30). According to local people, however, what remained as a free water surface is no longer accessible. About 30 years ago people used to enter the lake fishing for tilapia and eels, but now they rely on high floods that flush the fish from the outlet at the northern part of the lake. Basal rocks on Savai'i Island do not support a high volume of freshwater habitats. The only patch of rainforest situated at the NW part of the island has no surface water at all. There are inland lakes situated high in the mountainous areas, but the access to them was difficult and required a local guide who was not available at the time of the visit. Other freshwater lakes on Upolu Island were completely isolated and the access to them was possible only if one could find guides that could cut a trail to them. Lake Lanoto'o is a tourist attraction and accessible on a windy track which is now well cut through the vegetation. The trail has been provided

Figure 31. Warning sign on a potential water hazard.

with steps dug out on the ground and parapets for easy climbing up and down to the lake.

Apart from being in advanced stages in their natural development many potential Odonata habitats have also been modified for agricultural purposes. Taro fields were organised within former wetlands. Those still support Odonata communities that are relatively diverse for the small size of the islands and were found to be important larval habitat when fringe irrigation canals were well maintained.

A diverse assemblage of Odonata, including *Amorphostigma* sp., was also found around the tanks and ponds of an abandoned tilapia farm above Tula, on the east end of Tutuila, indicating that artificial habitats can be well-utilized by native Odonata on these islands.

In other cases filling has transformed freshwater habitats to land. Damp areas with potential to hold a particular freshwater aquatic assemblage were filled up with soil and now cannot be located. *A. interrupta*, for example was described by one male found in this kind of habitat that was not found during the present study even after consultation with local people.

Anthropogenic pressure on the other hand has had an obvious adverse effect on stream health. Many potentially good Odonata habitats suffered intensive pollution from household waste. Warning signs (Fig. 31) were posted at the entrance to streams containing water deemed potentially hazardous to health. When possible such places were avoided or entered with great caution. Domestic dogs were highly aggressive and posed another restriction to the sampling process.

For the aforementioned reasons it is highly recommended that all future scientific research be coordinated with local people. Relationships were built during the current study with the Samoan community and potential researchers could contact directly some of the authors or familiarise themselves in advance with governmental regulations ahead of planning field sampling. A special section published on the New Zealand Entomological Society web site explains the rules to do science on the Pacific islands with links to the necessary documents for research permits: http://ento.org.nz/tools-and-resources-2/insect-collecting-in-new-zealand-and-the-south-pacific/. This is the starting point for everyone interested in the entomology of the Pacific and must be checked for more recent updates.

The reward of doing science in these remote archipelagos is great as is obvious from the 'Result' section in this publication. Almost every sampled taxon provided some new or intriguing facts on their morphology that were found to be unique to Samoan representatives of otherwise widely distributed species or local endemics. More details on important discussion points are provided below as result of the detailed morphological investigation carried out in the laboratory.

Taxonomic notes

"Ischnurine complex"

The so called "Ischnurine complex" is perhaps the most debatable and challenging topic for every taxonomist dealing with the Samoan Odonata. The name itself is controversial because it is very close to Ischnurinae Fraser, 1957 (based on *Ischnura* Charpentier, 1840), which was proposed to accommodate 17 Odonata genera including the two Samoan endemics *Pacificagrion* and *Amorphostigma*. Ischnurinae, however, creates a homonymy to the scorpion family name Ischnuridae Simon, 1879 also given as a subfamily Ischnurinae under Scorpionidae Lattreille, 1802. This problem has been dealt with in two separate cases (3120 and 3120a) of the International Commission on Zoological Nomenclature (Fet & Bechly 2000, 2001). The issue was resolved by proposing a new family name Liochelidae Fet & Bechly, 2001 as a substitute to the scorpion family Ischnuridae and retaining subfamily Ischnurinae under Coenagrionidae Kirby, 1890 (Insecta: Odonata). This is a very interesting decision because it was taken in spite of the fact that Ischnurinae Fraser, 1957 is a junior homonym of Ischnuridae Simon, 1879. It was decided that the latter name should be discarded because *Ischnurus* C.L. Koch, 1837 (type genus of Ischnuridae Simon, 1879) is no longer in great use because it was a junior generic synonym of *Hormurus* Thorell, 1876. However, *Ischnura* is a cosmopolitan Odonata genus and is in wide use at present.

No case has been created for the Samoan "Ischnurine complex". This complex has never been formally described or recognised as a taxonomic category. Fraser (1953) had this name only in the title of a paper introducing new species, description of opposite sex of known species and further morphological details of species he described in his previous studies on Samoan Odonata (Fraser 1925, 1926, 1927). "Ischnurine complex" was not outlined and it is unclear as to what taxonomic level this grouping applied – genus or species. The name that Fraser selected implies a generic level, and possibly he meant to include closely related genera (some of them endemic). However, Fraser (1953) dealt with three genera, *Pacificagrion*, *Ischnura* and *Agriocnemis*, with the first only endemic to the Samoan archipelago. *Amorphostigma* is another endemic genus that was not treated in this study, but included within subfamily Ischnurinae later on (Fraser 1957). *Agriocnemis* on the other hand was proposed by Fraser (1957) as a type genus of a separate new subfamily Agriocneminae Fraser, 1957. If the grouping within this complex was meant to be at the species level then only endemic *Ischnura* must be considered in which case a better name would have been *Ischnura* complex, which was the name chosen by Donnelly (1986) in his report on Odonata collections from Samoa. However, in the discussion that follows Donnelly's study *Amorphostigma* was treated in the same section dealing with the *Ischnura* complex together with *Pacificagrion* and endemic *Ischnura* species. *Agriocnemis* was excluded from this analysis.

The matter is further complicated because Ischnurinae Fraser, 1957 was supposed to include genera in which females have "a prominent ventral spine (vulval spine) on the apical margin of segment 8 of the abdomen". This spine, however, is not developed in all species presently included in this subfamily. For example, females of both *Pacificagrion* and *Amorphostigma* lack this morphological structure. For all the reasons discussed above we consider Ischnurine (or *Ischnura*) complex inconsistent with any taxonomic rules or any other generic/species groupings and propose not to use it in future studies on Samoan Odonata.

The correct taxonomic position of the endemic Samoan *Ischnura* plus *Amorphostigma* and *Pacificagrion* remain to be resolved in future studies. Fraser (1927, 1953) described endemic species from holotype males and associated females by supposition based on general similarity between the two sexes. He did not collect any of those in order to associate males to females on the basis of direct field observations. For *Pacificagrion dolorosa* the author pointed out the considerable differences between the two sexes and suggested that the specimens he described may have belonged to an unknown species.

Fraser (1927) did not state the reason for placement of new species from Samoa within *Ischnura*. According to him, in habitus, *I. buxtoni* resembles the congeneric *I. senegalensis* (Rambur, 1842) which seems to be correct for the general body colouration, but not for the male appendages. Figures provided in the original description illustrate only *I. haemastigma* and compare it to *A. armstrongi*. The resemblance in the male appendages is remarkably high. Although not illustrated, the other two endemic species de-

scribed at the time (*I. albitsigma* and *I. chromostigma*) are probably close to *A. armstrongi* as far as the male appendages are concerned. This is apparent from the references in the original species description and comparison with the types investigated by photos only. The occipital area and spines on the hind femora also seem to be similar in *Amorphostigma* and Samoan *Ischnura*. However, other morphological features in *Amorphostigma*, like the unique pterostigma in males, lack of projections on the mesostigmal plate, and the blunt end of the eighth abdominal sternite, clearly differentiate it.

Fraser (1927) makes an interesting comment on the great similarity of male appendages *of I. albistigma* to "… a Tahitian species …" being "… almost identical …", but does not state the generic affinity of that species. So far three *Ischnura* species have been reported from Tahiti Island: *I. spinicauda* Brauer, 1865, *I. taitensis* Selys, 1876 and *I. cardinalis* Kimmins, 1929. Of these only *I. taitensis* has appendages that approach those of Samoan *Ischnura*. Austral Islands species, like *I. thelmae* Lieftinck, 1966 (endemic to Rapa Island) and to some extent *I. rurutana* (endemic to Rurutu Island) also approach Samoan *Ischnura*. Lieftinck (1966) pays particular attention to the great similarity of *I. thelmae* to *A. armstrongi*.

This short discussion aims at increasing the interest in Samoan and French Polynesian species presently placed in *Ischnura*. There seem to be a combination of morphological traits (large distance between occipital lobes which in most species are oblique and not bulging, horn-like projections on the mesostigmal plate, prenonal index, spines on the hind femora, male anal appendages) that warrant a separate generic status at least for Samoan taxa. However, none of the *Ischnura* described from Samoa were sampled during the present study and the types were investigated by photos only which is insufficient to provide a plausible taxonomy. Therefore, we refrain to continue with the taxonomic discussion at this stage.

Agriocnemis

Two species have been accepted as inhabitants of the Samoan archipelago (Marinov et al. 2013a). One of them *A. interrupta* Fraser, 1927 was not found during the present study. It was described from a single male specimen, which was found to be six mm larger than *A. exsudans* and arguably the largest representative of the genus, approaching the size of *Argiocnemis* Selys, 1877. Fraser (1927) provided dorsal and lateral views of the male appendages, which we find to be misleading. The description of the male says about the superior appendages that they are "... stoutly built, divaricate, equal in length to segment 10, the apices notched" whereas the inferior are "... almost hidden in the end of abdomen." Figure 1d in the original description shows the opposite arrangement – superior appendages much smaller than inferior. The figure may be true if it is flipped vertically, but in this case the larger inferior appendages are supposed to have a notch at the tip which is not shown on the figure. Also in general the description of the species is indistinguishable from *A. exsudans*. Wing venation was found to be the only feature that differs, with *A. interrupta* having 11 postnodal cross veins in the forewings and nine in the hind as opposed to eight and six, respectively, typical of *A. exsudans*. Those numbers varied among the specimens collected and

examined here, and in males they were nine to seven while in females they could be as high as 10 and eight, thus approaching those of *A. interrupta*. In the absence of good figures one may wonder if the larger size would be the only diagnostic feature to distinguish between the two species. The new measurements taken during our study show that single *A. exsudans* specimens approached *A. interrupta*, being four mm smaller. However, the size alone should not warrant a specific status as demonstrated by Marinov et al. (in press) for the New Zealand endemic genus *Xanthocnemis*. *X. sobrina* (McLachlan, 1873) was established for its large size (more than 15 mm larger than its congenerics) and small differences in the lower lobe of the superior appendages in males. Because of its great overall morphological similarity to *X. zealandica* (McLachlan, 1873) Moore (1989) suggested that behaviour traits, rather than morphological features, could help to differentiate *X. sobrina* from its allies. Finally Marinov et al. (in press) synonymised *X. sobrina* with the common New Zealand *X. zealandica* based on the detailed geometric morphometrics and molecular analyses. The number of the postnodal cross veins in *X. zealandica* could differ from 11 (forewings) and nine (hind wings) to 16 and 13 respectively depending on the size of the specimen (M. Marinov

Figure 32. Comparison between Pacific *Pseudagrion* spp.: a) *P. m. stainbergerorum* (Tonga), b) *P. samoense* (Samoa).

per. obs.). Therefore a careful re-examination of the holotype of *A. interrupta* is necessary to validate its status, because, as demonstrated above, the body size range could vary by as much as 5.2 mm for females and 5.3 mm for males.

Fraser (1927) apparently had a young male at the time of examination. About the same time Tillyard (1924) described *Agriocnemis vitiensis* n. sp. It is now considered as a junior synonym of the widely distributed *A. exsudans*, which is an idea discussed in Fraser (1925, 1927) because of the observed age-related morphological differences in other Zygoptera genera. Perhaps at the moment we are in a similar situation with *A. interrupta* and *A. exsudans* where we have the body size as the only way to reliably distinguish between the two taxa. We lack enough specimens for revision and no one had reported *A. interrupta* since its original description and description of what was believed to be a female of the species (Fraser 1953). Due to insufficient material, the suggestion for the moment is to retain the current taxonomic position of *A. interrupta* although it probably needs to be synonymised with *A. exsudans*. Moreover, describing the female *A. interrrupta*, Fraser (1953) pointed out that the abdomen was bright red from the seventh segment to the tip in a way typical of males. *A. exsudans* females differ in body colouration, being entirely bright red in teneral individuals and dark in adults.

Pseudagrion

Pacific *Pseudagrion* have been assigned to various taxonomic levels. Tillyard (1924) and Fraser (1925) preferred species status for *P. pacificum* (Fiji) and *P. samoense* (Samoa) respectively, while Marinov (2012a) suggested subspecific level for *P. m. stainbergerorum* from Tonga which correspondingly implied that other specimens from the Pacific identified as *P. microcephalum* should be considered as belonging to the nominate subspecies. The same nomenclature was used in Marinov (2013) where specimens from Tonga and Solomon Islands were compared, only adding extra diagnostic features from the shape of the superior appendages to distinguish between the two subspecies. For convenience this approach is maintained here, although the taxonomic position has to be revised including specimens from other parts of the *P. microcephalum* range. In fact Rambur (1842) described the holotype male from India. Detailed examinations of the male appendages may rearrange the nomenclature again assigning the Solomon Islands populations to a different than the nominate subspecies. In fact future studies on the genus may confirm the view expressed in Marinov (2012a) that all Pacific *Pacificagrion* taxa deserve subspecific status. The morphological analysis provided in the Results section above is indicative of the great similarities between the four investigated taxa. Figure 32 displays the great similarity in general habitus between congenerics from Tonga and Samoa. There are, however, small structural (male appendages) and colour (all body) features that in combination were found reliable enough to support the separation of the taxa. Geographic location of the study area could be used too, but before finally deciding upon the correct taxonomic position another test must be run including a larger sample size from Fiji. So far all conclusions were based on a single male used here as well as in the other two previous studies comparing Pacific *Pseudagrion* specimens (Marinov 2012a, 2013).

Anaciaeschna

Marinov et al. (2013a) commented on the taxonomic validity of *A. melanostoma*. It was questioned earlier in Marinov & Pikacha (2013) on the grounds of the variability of the features proposed as diagnostic characters in Lieftinck (1949) – dark front of head, dorsal incomplete antehumeral spots, reduced breadth of mes- and metepimeral bands, wings deeply stained with golden yellow, and reduced light spots on the abdominal segments. We here present more data on the variability of the frons which was one of the main characters proposed for establishing *melanostoma* as a new species. Apparently the purple area cannot be used as diagnostic because it varies even between specimens from the same area as demonstrated by the single male collected here and the one reported in Marinov et al. (2013a). Also the male appendages of the newly collected male *jaspidea* did not differ from *melanostoma* because they both appeared to be equally large at the bases. Male appendages are also identical to the illustrations provided in Needham (1935) *for A. jaspidea* from the Society Islands. Considering all previous discussions we propose to synonymise *melanostoma* with *jaspidea*.

Figure 33. Manu'a Islands: a) view of Ofu Island (with the bridge to Olosega on the far right) from the village of Olosega, b) view from the beach on Ofu showing eastern peaks of Ofu, Olosega and Ta'u in the distance.

Figure 34. *Lathrecista asiatica*. Note the apical dark spot is obscure to almost non-existent.

Hemicordulia

Hemicordulia specimens collected from the Samoan archipelago have been variously assigned to *H. oceanica* Selys, 1871 (Fraser 1925) or *H. assimilis oceanica* Selys, 1871 (Fraser 1927) until Lieftinck (1975) established *H. hilaris* spec. nov. for New Caledonian specimens and included specimens collected from Fiji, Tonga and Samoa within this species concept. Lieftinck (1975) also provided a detailed description of *H. oceanica* known from the Society Islands only and compared it to *H. hilaris*. Donnelly (1986) found that both *H. hilaris* and *H. pacifica* were widespread on Upolu with the latter very common on Tutuila also. We here confirm this observation and add important diagnostic features which will facilitate species identification in the field. The characters illustrated in the Results section should be used in combination because of the observed variation between specimens within the Samoan archipelago and other parts of the Pacific. Young female *H. hilaris* from Fiji, for example, did not have the light brown apical spot on the wing, but had a completely transparent wing membrane. If this brown spot is typical of young females of Samoa only or is another intra-population variation remains to be determined in future studies. Colouration on the labrum is another very variable feature. Generally *pacifica* has a darker colouration compared to

hilaris in which the labrum is almost always bright yellow. This comparison excludes *H. cupricolor* which was not encountered during the current study. Marinov et al. (2013a) reported *H. cupricolor* in Samoa based on one female collected during the night. During the present research a large *Hemicordulia* was observed flying in day light, but was not properly identified. In size it was bigger than *pacifica* and *hilaris*. It was provisionally identified as *cupricolor* based on the size, but the presence of *cupricolor* in that locality (cf. Results) must be confirmed. Fraser (1927) reported on another *Hemicordulia* from Ta'u Island, which lacked the last abdominal segments and therefore remained identified to genus level only. Fraser concluded that what remained of the body was identical to *H. tau* Selys, 1871, which is a species with strikingly contrasting body colouration of bright yellow and dark areas. All so far established for sure is that *Hemicordulia* in Samoa have their bodies dark with very faint spots in *hilaris* only. Marinov (2012b) commented on age-related variations in the body colouration of *H. hilaris*. Young specimens tend to have larger and brighter yellow areas, but they all follow the general pattern observed for mature ones. Keeping in mind that: 1) Fraser claimed it was similar to *tau* long before the description of *hilaris*, and 2) the range of *tau* is far away from Samoa, it is possible that this specimen either belonged to a young *hilaris*, to a new species or was mislabelled. Ta'u Island has never been investigated before. With its relative isolation and the fact that it is the only island within the Manu'a group (Fig. 33) that has a permanent stream, it will be a rewarding area for future studies.

Lathrecista

L. asiatica from the Samoan archipelago (Fig. 34) show some morphological features that differ from specimens collected from other Pacific island groups like Fiji and Tonga. Donnelly (1986) for the first time reported on the size variations of specimens found at low elevations in Upolu and Savai'i which were smaller than their counterparts from Fiji. Although not reported in Marinov et al. (2013a) the *L. asiatica* specimens from Samoa investigated in that study were smaller too and comparable to the specimens collected in the present study. We can therefore confirm Donnelly's statement and add that our Samoan specimens also differed from those collected from Fiji and Tonga. Detailed investigations revealed other differences between Samoan specimens and those from other Pacific archipelagos. Those differences were illustrated and noted above. Whether those morphological features could be considered as diagnostic and sufficient to validate assignation of a new subspecies for Samoan populations, are two questions that require additional study. The sample size (1 female, 2 males) is too small and features based on colour variations are often unreliable.

Rhyothemis

R. regia chalcoptilon is the preferred name for the Samoan specimens based on Lieftinck's (1959) paper concluding the taxonomic discussion between him (Lieftinck 1942) and Fraser (1956). At present this subspecies is considered to be distributed across a very large territory from the Mariana Islands to Samoa. The current study shows some slight variations in the wing colourations which were observed on specimens from the same locality. They are likely to occur on individuals from the entire range and this

should be taken into consideration in other studies before proposing any change in the taxonomic status. Lieftinck (1962) presented an illustration of specimens from the Mariana Islands which are identical to what is considered here as the rarer morphological variation sampled within the Samoan archipelago.

Tramea

The taxonomy of the Pacific island *Tramea* has been discussed in several recent studies (Marinov 2013, Marinov et al. 2013a). It was suggested that the dark area on the base of the hind wing was too variable to be diagnostic and should be abandoned in any studies of the genus. The variability of this character was clearly demonstrated in Marinov (2013) for specimens inhabiting the same wetland in the Kingdom of Tonga. Here we present more evidence in support of this view. The location and shape of the dark spots in some specimens from both Tonga and Samoa approached the pattern described for *T. transmarina intersecta* Lieftinck, 1975 from New Caledonia. Therefore specimens reported in Marinov et al. (2013b) were compared here to specimens from Fiji, Tonga and Samoa (Fig. 20). The dark area at the base of the hind wing was found to be an unreliable character for the New Caledonian specimens too. It varied with one of the specimens having a complete dark band rather than two separate spots as in the holotype. Lieftinck (1975) did not clearly specify the rationale for establishing *T. t. intersecta* subspec. nov. and how to differentiate it from other subspecies within the Pacific. Most probably he regarded the colouration of the base of the hind wings as diagnostic because he used it for comparison with other New Caledonian specimens (including a teneral female) and a mature female from Vanuatu. It is important to note that even in the original description Lieftinck (1975) reported a variation of the wing colouration in which the two spots were connected outwardly and "... thus approaching the condition seen in nominotypical *transmarina*". In light of the new findings one may question the validity of this subspecies if its designation was based on such a variable character as the wing colouration. The here reported morphological comparison revealed other characters that differed slightly in New Caledonian specimens compared to those from Fiji, Samoa and Tonga. Those were the colouration of the head, thorax and abdominal tip (cf. Fig. 20 above). Due to the small sample size (three males) and the fact that those differences are again associated with the colour intensity, we do not propose any taxonomic change for *T. t. intersecta*, but suggest that characters other than the dark hind wing area should be employed in investigating the validity of this taxon in future studies.

Marinov et al. (2013a) provided a photo of a female that was tentatively identified as *T. transmarina*. They were, however, unsure if the intensity of the colouration of the frons was a sex related character. Both female specimens encountered during the present study had the same colouration as the Figure (6a) in Marinov et al. (2013a) and one of them was caught in copula with a typical *T. transmarina*. Therefore, we confirm the tentative identification of the female in Marinov et al. (2013a) to be *T. transmarina*.

The last important topic related to Samoan *Tramea* involves two other species from the same family – *Macrodiplax cora* and *Pantala flavescens*. *M. cora* has been the

focus of many recent visits to the Pacific islands because it was so far not recorded amongst the sampled specimens from Solomon Islands (Marinov & Pikacha 2013), Fiji (Marinov 2011), New Caledonia (Marinov et al. 2013b), and Tonga (Marinov 2012a, 2013). Previous studies reported it from various areas including Samoa (Fraser 1925, 1927). Fraser (1927) thinks it could be overlooked in flight because of its resemblance to other two common libellulids – *P. flavescens* and *T. transmarina*. Now that the species was truly detected in flight several hints could be pointed out for in-flight recognition. There are two points of comparison: the colouration and the shape. The deep red colour is typical of *M. cora* and *T. transmarina* because *P. flavescens* may look reddish, but never becomes as dark red as the other two. On the other hand *T. transmarina* has reddish wing veins which give the wing surface a brighter colour than *M. cora* and can be recognised in flight from a distance. Shape is more difficult as it takes practice observing large number of individuals in flight. Generally *T. transmarina* looks stouter than the other two. Both *P. flavescens* and *M. cora* are more slender with the first being slightly more elongated and slimmer looking than the second. *M. cora* resembles a larger *D. bipunctata* in body proportions and colouration.

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